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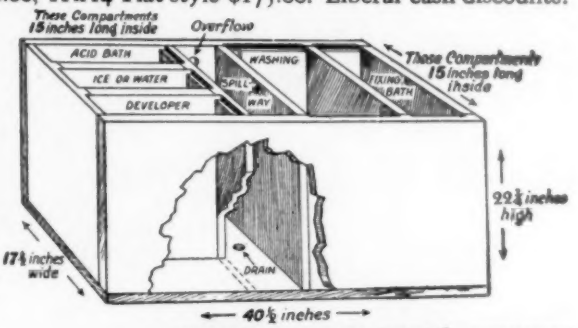

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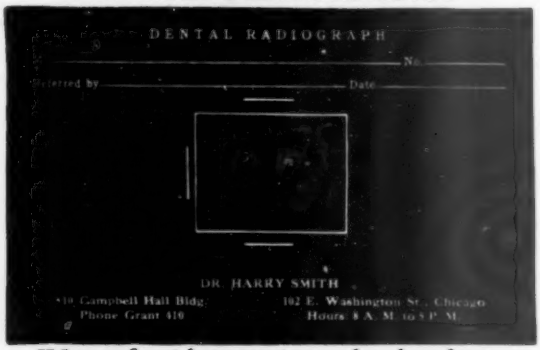

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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

VOL. XXI JANUARY, 1929 No. 1

RADIUM THERAPY OF CANCER AT THE RADIUM INSTITUTE OF PARIS

TECHNIQUE, BIOLOGICAL PRINCIPLES AND RESULTS*

BY DR. CL. REGAUD

Professor of the Pasteur Institute, Director of the Laboratory of Radiophysiology of the Institute of Radium of the University of Paris

PARIS, FRANCE

RADIUM and roentgen therapy cannot and should not be divorced from surgery in the modern treatment of cancer. If, in spite of this, I limit my remarks to the progress of radium therapy only, I do not wish to leave the impression that such therapy at the Radium Institute of Paris is considered more important than the other methods of treatment of cancer. Great progress has been accomplished in radium therapy within the last few years. It is, therefore, interesting to present this subject separately at the present time.[1]

This progress is twofold: first, there is a better understanding of the properties of cancer tissue, and the action of radiation on it, and second, increased experience in the application of radium in the treatment of cancer has improved the technique, and this has been materially aided by the greater quantities of radium which are now available. Improvement in the technique will be discussed first, while the mechanism of biologic action of gamma rays on tissues, especially neoplastic tissues, will be discussed in the latter part of the paper.

Evaluation of the effects of therapeutic agents used in the treatment of cancer is difficult and can be considered reliable only if statistics are available based on correct and unimpeachable information. Many publications on the question of radiotherapy of cancer lack complete and exact data. Statistics, according to the manner in which they are presented, may conceal all imaginable transitions between intentional misstatements, honest delusions or the absolute truth, and the value of the reports must be modified in accordance with this information. It is the duty of scientific institutions to establish unquestionably correct statistics of the cure of cancer, using the same impartiality as is employed in problems of pure biology.

When cures are spoken of at the Radium Institute, it is presupposed that the patient has been free from clinical evidence of disease for a reasonable length of time. This time varies with different types of cancers, thus, for example, the victims of cancer of the skin and mouth must be free from clini-

[1] It is not my intention to give here a complete exposition of present-day technique of radium therapy. I wish only to acquaint American radium therapists with the principles followed at the Radium Institute of Paris. I therefore beg the indulgence of the readers if the scope of this article appears to be somewhat limited.

* Address delivered before the New York Roentgen Society at the Montefiore Hospital, New York, Oct. 11, 1926. Translated from the French by Dr. Maurice Lenz, New York City. In spite of the delay in publication of this article it represents the present-day ideas on this subject at the Institute. The results of 1925 and 1926 have been added in and statistics have been revised up to the last examination of patients on December 31, 1927.

cal evidence of the disease for a period of at least three years; of cancer of the uterine cervix for five years, and of cancer of the breast for ten years. The term "cured" does not include such palliation as improvement in the general condition of the patient, prolongation of life, diminution in the size of the tumor or retardation of the growth of the neoplasm. These results may be very desirable but are insufficient for evaluation of the comparative merits of surgery and radium therapy.

The statistics of the Therapeutic Department of the Radium Institute at the Curie Foundation of Paris have the following basis:

(*a*) The total statistics consist of the total number of treated cases, grouped according to histology and localization.

(*b*) The cases are also classified into categories depending upon the anatomico-clinical character of the lesion.

(*c*) The therapeutic method used is left out of consideration and cases are designated impartially as failures, negative cases or cures.

(*d*) Revised statistics will be published from time to time until the problem on which they have a bearing has been definitely settled. The work undertaken is considerable as it must be based on a great number of cases. Up to the present, we have only been able to prepare the statistics for a few localizations of cancer: cervix of the uterus, skin and mouth. For other localizations, the work has not progressed sufficiently to permit any more than the expression of an opinion without the support of exact statistics based on great numbers.[1]

PART I

TECHNIQUE OF RADIUM THERAPY

Three methods of application of radium of cancer, employed by our predecessors since the beginning of radium therapy have proved valuable and are in use today:

A. The placing of radium in containers into the natural cavities and channels of the body in contact with the neoplasm (intracavity irradiation).

B. The interstitial introduction of radium in containers into the neoplasm after piercing the covering surface of skin, mucous or serous membrane.

C. The application of radium on the surface of the body overlying the neoplasm.

D. There is a fourth method used at present which was unknown to the pioneer radium therapists; this is irradiation of the neoplasm through the skin at a distance from it. The possibility of utilization of greater quantities of radioactive substances in a manner similar to the employment of the roentgen tube, had been considered long ago, but only in the last few years has it been practically employed in this fashion in several of the larger radium institutes.

A. *Radium Therapy through Natural Cavities and Channels of the Body*. In spite of numerous attempts to use natural cavities of the body for placing radium in contact with neoplastic tissue, this method has been discarded except in cancer of the uterus where it is still retained as the best available method. Here, this pocket edition of the roentgen tube (as radium was named by A. Béclère) is still used successfully in early cases by being placed in the utero-vaginal cavity.

Radium placed in the rectum and urethra in cases of cancer of the prostate and bladder at times gives palliative results (Young, 1922; 1926). Cures, however, are exceptional by this method of treatment.

The same may be said of irradiation by radium placed intrarectally for cancer of the rectum. Moreover, severe burns of the normal mucous membrane in the vicinity of the tumor have frequently complicated this mode of application. Our results have been so discouraging from this method of treatment that we have discontinued its use at the Radium Institute.

Cure of cancer of the esophagus by the introduction of radium is exceptional, and can be hoped for only in small shallow growths which are rarely, if ever, observed. Intra-esophageal radium therapy produces only palliative results, and is used for temporary improvement, and at times for prolongation of life.

Intracavity radium therapy has failed in

[1] The work reported in this article represents part of the therapeutic work done under my direction by a staff of numerous collaborators; those who have taken an important part in the treatment of cancerous localizations described here are Drs. H. Coutard, A. Hautant, Ant. Lacassagne, O. Monod, J. Pierquin, G. Richard and J. Roux-Berger; also Mlle. M. Thurneyssen who is in charge of keeping our records up to date.

cancers of the larynx and the upper air and alimentary passages, except for temporary improvement. Other methods of application may give better results in this variety of cancer. There are many reasons for the poor results of intracavity radium therapy of cancer. In some cancers which are thus irradiated their histological structure seems to render them resistant to radium therapy (e.g., adenocarcinoma of the rectum). This point will be discussed more fully later on. The radium therapy of all cancers arising within natural cavities of the body is complicated by the following difficulties: Access for radiation is available only to the central part of the neoplasm, i.e., the part immediately in contact with the radiating focus; the cavities of these invaded viscera are narrow and can be dilated only very slightly, especially as the mucous membrane is usually thin and vulnerable. These difficulties bring about inexact application, danger of over-irradiation and burns of the parts near the radiating focus, especially if strong doses are used, and under-irradiation of distant parts if a weaker radiation is employed. Homogeneous distribution of radiation throughout the neoplasm by this method is possible only if the thickness of the neoplasm is so inconsiderable that the outlying portions of the neoplasm may be reached with a fairly equal dose, by irradiation from within the cavity. The success of this method of radium therapy in cancer of the uterine cervix can be explained by the marked radiosensitivity of the majority of these cancers, by their advantageous anatomical position and by the exceptional resistance of the normal tissues of the uterus and vagina against strong doses of radiation. Even here, however, success is limited to cancers which have not as yet invaded the outlying portions of the parametrial connective tissue and pelvic lymphatics. When this extension has taken place, external roentgen or radium therapy has to be added to care for the invasion of the outlying portions. Details of our radiotherapeutic procedures will not be given here as this information has been published and can easily be referred to.[1]

Our results which have been completed and revised during the last year are appended in the accompanying tables which give the statistics of cases of cancer of the uterus treated by radium alone or in association with roentgen rays. They comprise cases treated up to December 31, 1926, and reviewed December 31, 1927.

Of 678 cases which compose Table 1, 68 were eliminated because they did not have any bearing upon the radiotherapeutic

[1] Report read before the Congress of the Society of International Surgery in 1926. A description of the uterovaginal technique of this treatment was published by Lenz in this Journal March, 1927, pp. 335–342.

TABLE 1

CANCER OF THE CERVIX UTERI

STATISTICS OF TOTAL TREATED CASES AND RESULTS, 1919–1926

(Revised Dec. 31, 1927)

Years	Years Since Treatment	Total Number of Treated Cases	Cases Eliminated from These Statistics	Cases Used for Statistics	Failures of Radiotherapy			Success of Radiotherapy	
					Number of Women Dead Not Cured by Radiation	Number of Women Living Not Cured	Number of Women Living Cured by Additional Hysterectomy	Number of Women Living Cured by Radiation	Percentage of Cures of the Retained Cases
1919	8 to 9	103	16	87	79	..	1	7	8.04
1920	7 to 8	98	9	89	72	1	..	16	17.9
1921	6 to 7	48	2	46	32	2	1	11	23.9
1922	5 to 6	69	9	60	41	3	..	16	26.6
1923	4 to 5	85	8	77	49	2	1	25	32.4
1924	3 to 4	80	11	69	35	5	..	29	42.0
1925	2 to 3	97	8	89	39	8	..	42	47.1
1926	1 to 2	98	5	93	26	30	..	37	39.7
Totals.....	.....	678	68	610	373	51	3	183	Mean: 30%

value of our method. The following are the reasons for eliminating them:

Patients cured but lacking preceding histologic examination	4
Patients lost from view less than five years after treatment; free from symptoms of cancer when last seen	22
Patients treated by radiation and later hysterectomized without a histologic examination, or dead from the operation where the subsequent histologic examination did not disclose any cancer	6
Patients in whom the treatment could not be completed	28
Patients apparently cured of cancer, but dead of an intercurrent illness less than five years after treatment	8
A total of	68

Table I gives the total statistics of the cases. It shows that 30 per cent of all patients were free from clinical evidence of cancer after a survival varying from one to nine years. Those well more than five years following treatment were 8 per cent for patients treated in 1919; 17.9 per cent for those treated in 1920; 23.9 per cent treated in 1921, and 26 per cent treated in 1922. This increase in the number of successful five year results points to gradual improvement in technique. The marked increase in the number of successful cases which are less than five years after treatment may be partly accounted for by the insufficient time which had elapsed after treatment; 32.4 per cent of cases which were four to five years after treatment were free from clinical evidence of disease, while 39.7 per cent of cases were free from clinical evidence of disease one to two years after treatment. This last number will, undoubtedly, be smaller when the results are revised within the next few years.[1]

Table II gives the statistics of early cases.

Among 678 treated cases, there were 79, i.e., 11.65 per cent of the first class (lesions limited to the cervix; early operable cases); 61 of these cases are available for statistical purposes. Of these, 60.6 per cent were free from clinical evidence of the disease for periods varying from one to nine years. It should be noted that the percentage of cures lasting five years or longer was 33.3 per cent for the cases in the years 1919–1922. These poor results were undoubtedly due to the failure of treatments given in 1919 and 1920. Our uterovaginal technique of treatment had not been standardized up to the year 1920; since that time, however, it has not been altered.

[1] The temporary setback which our results of 1926 (39.7 per cent) suffered when compared to those of 1925 (47.1 per cent) is due to the greater number of unfavorable cases which were accepted for treatment and the greater care used in classifying cases as cured.

TABLE II

CANCERS OF THE CERVIX UTERI
STATISTICS OF OPERABLE CASES, 1919–1926
(Revised Dec. 31, 1927)

Years	Years Since Treatment	Number of Treated Cases	Cases Used for Statistics	Women Cured by Radiation	Percentage of Cures of the Retained Cases
1919	8 to 9	11	5	0	.....
1920	7 to 8	13	10	2	20.0
1921	6 to 7	11	10	4	40.0
1922	5 to 6	8	5	4	80.0
1923	4 to 5	12	11	9	81.8
1924	3 to 4	7	6	6	100.0
1925	2 to 3	10	8	6	75.0
1926	1 to 2	7	6	6	100.0
Totals....	.....	79	61	37	Mean: 60.6%

TABLE III

CANCERS OF THE CERVIX UTERI
STATISTICS OF CASES OF BORDERLINE OPERABILITY, 1919–1926
(Revised Dec. 31, 1927)

Years	Years Since Treatment	Number of Treated Cases	Cases Used for Statistics	Women Cured by Radiation	Percentage of Cures of the Retained Cases
1919	8 to 9	23	18	6	33.3
1920	7 to 8	34	33	7	21.2
1921	6 to 7	18	17	4	23.5
1922	5 to 6	22	21	6	28.5
1923	4 to 5	26	23	10	43.4
1924	3 to 4	20	17	11	64.7
1925	2 to 3	19	18	8	44.4
1926	1 to 2	30	29	14	48.2
Totals....	.....	192	176	66	Mean: 37.5%

Table III gives statistics of more unfavorable cases, that is, where an invasion had begun into the cul-de-sacs and parametria, but where the uterus was still mobile and hysterectomy was possible though with the possibility that the invaded parts would be incompletely removed. One hundred and ninety-two cases, i.e., 28.3 per cent of the 678 treated cases belong in this group; 176 of these may be used for statistical purposes and of these 37.5 per cent were free

from clinical evidence of disease one to nine years following treatment. Of the patients treated from 1919 to 1922, 25.8 per cent have been well for more than five years.

TABLE IV

CANCERS OF THE CERVIX UTERI
STATISTICS OF INOPERABLE CASES, 1919–1926
(Revised Dec. 31, 1927)

Years	Years Since Treatment	Total Number of Treated Cases	Cases Used for Statistics	Women Cured by Radiation	Percentage of Cures of the Retained Cases
1919	8 to 9	69	64	2	3.22
1920	7 to 8	51	46	7	15.2
1921	6 to 7	19	19	3	15.7
1922	5 to 6	39	34	6	17.6
1923	4 to 5	47	43	6	13.9
1924	3 to 4	53	46	12	26.0
1925	2 to 3	68	63	28	44.4
1926	1 to 2	61	58	17	29.3
Totals....	.....	407	373	81	Mean: 21.7%

Table IV gives the statistics of very unfavorable cases. Of the 678 cases treated, 407, i.e., 60 per cent are classified as inoperable or third degree, and desperate or fourth degree; 373 of these cases may be used for statistical purposes. Of these 21.7 per cent were free from clinical evidence of disease one to nine years after treatment. Of those which were free from clinical evidence of disease more than five years 3.22 per cent had been treated in 1919; 15.2 per cent in 1920; 15.7 per cent in 1921 and 17.6 per cent in 1922.

It is easy to appreciate the progress made from year to year when one considers the fate of patients after their treatment, as has been done in Table V.

TABLE V

STATISTICS OF PATIENTS TREATED FOR CANCER OF THE CERVIX UTERI
From 1919 to 1926 Inclusive, and Living One Year after Treatment

Years	Patients Treated Retained Cases	Patients Living One Year after Treatment	Percentage
1919	87	30	34.4
1920	89	48	53.9
1921	46	28	60.8
1922	60	32	53.3
1923	77	47	61.0
1924	69	46	66.6
1925	89	66	74.1
1926	93	67	72.0
Total.....	610	..	....

This table shows that considerable progress was made between the years of 1919 and 1926.

Among 87 patients treated in 1919 only 30, i.e., 34.4 per cent were alive one year later. Among 93 patients treated in 1926, 67, i.e., 72 per cent were alive one year later.

This improvement becomes more evident when the five year results of patients treated from 1923 to 1926 are considered.

The total of five year cures for the years 1919, 1920, 1921 and 1922 was 17.7 per cent. We hope this number will be doubled when the results of four more years are added to those already mentioned.

Our technique for the treatment of cervical cancer was poor during the first few years when compared with that which we employ today.

B. *Interstitial Radium Therapy and Radium Surgery.* The introduction into the tissues of radium in containers is nearly as old as radium therapy itself. This application may be carried out by several methods:

1. Inserting and permanently leaving within the tissues minute capillary tubes containing radon. The capillaries are made of glass, gold or platinum and are called seeds.

2. The temporary introduction of metallic needles into the tissues after piercing the natural coverings overlying the neoplasm—radium puncture.

3. Preliminary preparation by surgery, facilitating access for subsequent radium application—radium surgery.

1. The seeds are an ingenious method suggested by Duane (1916) and first applied by Janeway at the Memorial Hospital (since 1917). Remarkable improvement in the results, especially those of cancer of the mouth, followed the gradual perfection of this method. At the first International Congress of Radiology in London in 1925, Quick submitted statistics of cases of cancer of the tongue thus treated, which were good. There are several objections to this method however. The radiation coming from the seeds acts as a diffuse caustic and frequently produces

early or late radionecrosis of the treated tissues. While this objection has been partly overcome by the substitution of gold for the glass wall (Failla, 1925), the thickness of the gold should be increased to 0.4 or 0.5 mm. if principles of radiotherapy are to be followed to their logical conclusion. It may also be questioned whether such foreign bodies as seeds may be left permanently in the tissues with impunity. Accurate and uniform spacing of seeds, which is essential for homogenous irradiation, is difficult, except in small and thin neoplasms. I, therefore, believe that this method of interstitial radium therapy will be discarded in the majority of cases in favor of removable needles, i.e., radium puncture.

2. It was Stevenson who first introduced a tube of emanation into a metal needle in 1914. He used steel needles offering little filtration. The needles were left in for a short time, and the radiation was effective only at the expense of simultaneous massive radionecrosis in the immediate neighborhood of the needle. The principle, however, appeared correct to mount a radioactive tube within a sharp-pointed container for the introduction into the tissues, so as to avoid the necessity of preliminary perforation of the surface by a trocar or scalpel. This procedure has been perfected at the Radium Institute of Paris. Since my initial publication (1920, *b*) we have standardized the method and it has given us the best existing statistics for the treatment of cancer of the tongue (Regaud, 1925, *b*, Roux-Berger and Monod, 1927). Two methods of procedure have been employed for radium puncture.

(*a*) Proust and his collaborators, Mallet and de Nabias, have used for the past few years small platinum tubes to which is attached a metallic thread. These tubes are 10 mm. in length and originally had a wall thickness of 0.5 mm. Lately this has been increased to 2 mm., without apparently improving the method. The tubes are inserted into the tissues by means of a trocar and stylet as practiced by the pioneers of radium therapy. They are withdrawn when the treatment has been finished. Muir (1926) recommends the employment of even smaller removable tubes containing a capillary of radon. A silk thread attached to the end of the tube makes it removable. The tubes are introduced in the same manner as seeds, and the wall thickness of platinum is only 0.3 mm. Their size and filter lay them open to the same objections as seeds.

(*b*) We have been using platinum irridium needles, hollowed out from point to eye, at the Radium Institute of Paris for the past eight years. The needles have a wall thickness of 0.4–0.5 mm. and vary in length, so that appropriate sizes can be chosen according to the thickness of the tissue which is to be irradiated. The needles hold one or more cells, 15 mm. in length. These cells contain radium element, or preferably radon. In longer needles two and sometimes three of these cells are placed end to end within the cavity of the needle and form a practically continuous radiating focus of 15 to 45 mm. length. The needles are inserted through the covering surface directly into the tissues to be irradiated. Special forceps and pushers are employed for this purpose. The needles have a double eye, which accommodates two silk threads. Once the needle is in place, one of the threads is used as a suture to fasten the needle to the skin or mucous membrane, and is cut short, while the second thread is permitted to remain long so as to facilitate the later removal of the needle. When the desired radiation dose has been administered, the retaining suture is cut and the needle is removed by pulling on the longer safety thread.

This procedure has the following advantages which seem important: The needles are introduced directly, without the aid of a trocar. During insertion they may be accurately directed by holding them rigidly at the end of special forceps, and unequal spacing which causes inequality of the dose may thus be avoided. Once in place, they are immobilized by suture.[1] Needles may be chosen in any desired length, yet having the same radioactivity per millimeter. A

[1] When needles are inserted parallel to each other, according to a plan made on the skin or mucous membrane (Figs. 1 and 2) it is frequently unnecessary to suture them. It suffices to arrange them in apposition to each other and to tie the strings of the opposing needles on top of the skin or mucous membrane, as their long size holds them in place.

Fig. 1. A case of epithelioma of the skin treated by radium puncture. B., aged fifty-four; epidermoid carcinoma of the right commissure of the lips; treated in February, 1921. Initial stage—relatively small ulceration, extensive infiltration of the lips and cheek.

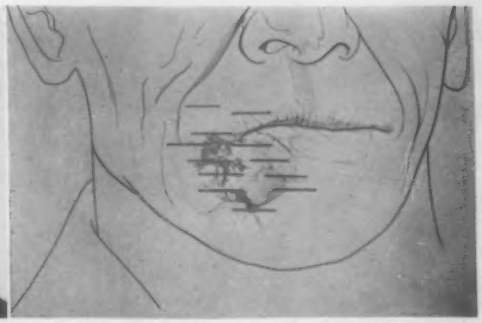

Fig. 2. Same patient as in Figure 1. Arrangement of foci containing radon.

Twelve platinum needles, the walls of which were 0.4 mm. thick, were inserted into the neoplasm. Each needle contained one tube of radon 15 mm. long so that the total radiating focus of all the needles combined was 18 cm. The initial total charge was 40.42. mc. The charge remaining after the completion of the treatment was 13.94 millicuries destroyed. The needles were introduced in opposite directions and their threads were tied together above the skin. The needles remained in place for eight days without interruption.

long total radiating focus may thus be obtained.[1] Nearly all beta rays are filtered out by the 0.5 mm. of platinum.

When radium puncture was first begun it was thought that it might become the method of choice in the majority of cancers. Instead, its use has been gradually restricted so that at present it is employed only for cancer of the tongue, and at times for thick or exuberant cancers of the skin, some cancers of the breast, some cancers of the soft palate and floor of the mouth. Difficulty is encountered when homogeneous irradiation of extensively invaded areas is attempted by this method. The weak filtration of the radiating foci favor late radionecrosis. It may also be that the traumatism of radium punctures favors the occurrence of metastasis in cancers which normally have this tendency, e.g., some varieties of breast cancer.

Figures 1, 2 and 3 illustrate an extensive epithelioma of the commissure of the lips and of the cheek which was treated by radium puncture (this method we use only exceptionally in such cases). The patient remained well for six years, but as result of an injury in 1923 a late radionecrosis of the bone and skin developed which healed later.

The schematic Figures 4 and 5 represent a case of epithelioma of the tongue.

[1] Under these conditions the dose administered per centimeter length of the radiating focus is weak. It varies between 0.5 and 0.7 millicuries destroyed per centimeter, and radionecrosis is therefore rare. The total length of this radiating focus, however, may be considerable: If the radium cells used in the interstitial irradiation of an average tongue cancer of moderate extent were placed end to end, their total length would amount to 30 cm. or more.

Our results in cases of cancer of the tongue and floor of the mouth treated by radium puncture up to the end of 1923 were reported by me at the First International

Fig. 3. Same patient as in Figure 1, four months after treatment.

One year later, in June, 1922, the patient received a violent blow to the treated region. A canine tooth which was partly broken off by the blow had to be removed. At this site there developed a late radionecrosis. This at first involved the maxilla, later the buccal mucous membrane and lastly the skin. A bony sequestrum was eliminated through the cutaneous ulceration in 1924 leaving a fistula which later was closed by plastic operation.

Congress of Radiology in London in 1925, and were published by Lenz in 1926.

Table VI gives the statistics of our patients treated before December 31, 1925, with revision of patients on December 31, 1927. These results were published by Roux-Berger and Monod (1927).

TABLE VI

CANCERS OF THE TONGUE AND OF FLOOR OF THE MOUTH
TOTAL STATISTICS OF TREATED CASES AND RESULTS, 1920–1926
(Revised Dec. 31, 1927)

Years	1920	1921	1922	1923	1924	1925	1926	Totals	Percentage
Number of treated cases	55	41	35	56	59	65	56	367	....
Cases which were eliminated	2	6	2	2	4	5	2	23	....
Cases retained for statistics	53	35	33	54	55	60	54	344	....
I. Anterior dorso-lingual localization	20	22	19	24	34	39	27	185	....
A. Complete cure	5	6	3	6	9	9	11	49	26.4
B. Cure of local lesion of tongue. Death from secondary adenopathy	6	7	8	10	7	4	4	46	24.8
C. Failure to arrest primary lesion of tongue	9	9	8	8	18	26	12	90	48.6
Permanent arrest of primary localization considered by itself	..	..	..	..	..	..	..	95	51.3
II. Posterior dorso-lingual localization	16	5	6	18	14	12	11	82	....
A. Complete cure	1	2	3	1	2	3	4	16	19.5
B. Cure of local lesion of tongue. Death from secondary adenopathy	2	0	0	5	4	2	1	14	17.0
C. Failure to arrest primary lesion of tongue	13	3	3	12	8	7	6	52	63.4
Permanent arrest of primary localization considered by itself	..	..	..	..	..	..	..	30	36.5
III. Infra-lingual localization	17	8	8	12	7	9	16	77	....
A. Complete cure	0	3	0	3	0	5	6	17	22.0
B. Cure of local lesion of tongue. Death from secondary adenopathy	3	2	0	1	2	0	1	9	11.6
C. Failure to arrest primary localization	14	3	8	8	5	4	9	51	66.2
Permanent arrest of primary localization considered by itself	..	..	..	..	..	..	..	26	33.7
IV. All localizations combined	53	35	33	54	55	60	54	344	....
A. Complete cure	6	11	6	10	11	17	21	82	23.8
B. Cure of local lesion of tongue. Death from secondary adenopathy	11	9	8	16	13	6	6	69	20.0
C. Failure to arrest primary lesion of tongue	36	15	19	28	31	37	27	193	56.1
Permanent arrest of primary localization considered by itself	..	..	..	..	..	..	..	151	43.8

The most favorable localization for therapy in cancer of the tongue is the anterior half of the dorsum and the borders; 26.4 per cent complete cures have been obtained in these localizations. To this may be added 24 per cent more of patients whose primary tongue lesion was cured while the metastatic glands were not so influenced. This makes a total of 51 per cent of eradication of the primary lesion without consideration of failure to arrest the growth of metastatic node deposits.

The posterior half of the dorsum of the tongue (its pharyngeal part), the infralingual portion (its under surface), and the floor of the mouth are less favorable; 19.5 per cent of cases of the first mentioned localization have been cured completely. In the second localization, 22 per cent complete cures and 33.7 per cent cures of the primary localizations alone are available. I believe, however, that the use of external radium therapy at a distance will supplant radium puncture in these cases and that the results will improve.

The total results for all these localizations are 24 per cent complete cures, and 44 per cent cures of the primary lesion only. It should be remembered that these figures are based on cases of which only 20 per cent were operable when submitted to the treatment.

We do not advise the treatment of invaded glands by radium puncture. At

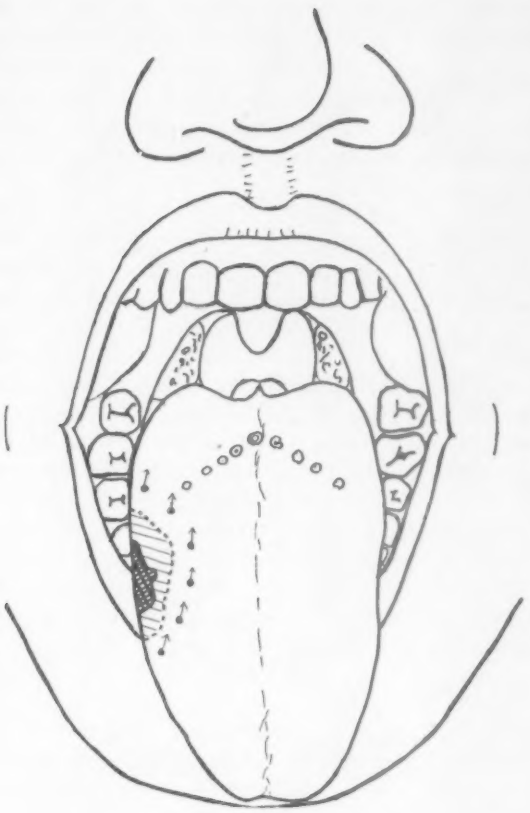

Fig. 4.

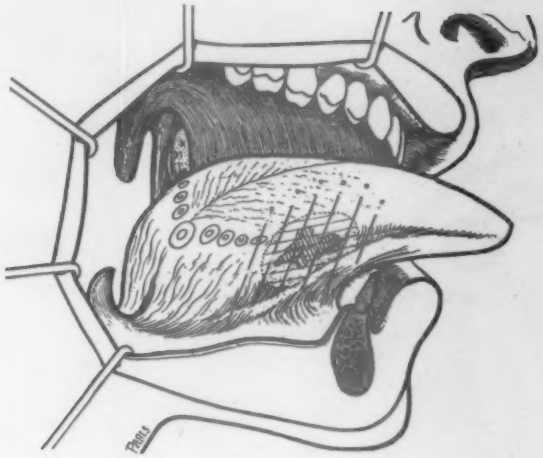

Fig. 5.

Figs. 4 and 5. Plan of the arrangement of radium puncture in relation to the lesion in a case of epithelioma of the right border of the tongue which was cured.

D., aged fifty-eight, treated from Oct. 23 to Nov. 9, 1924.

The ulcerated part is shaded by squares; it is surrounded by a zone of induration marked by transverse lines. The dots on the arrows denote the places of insertion, while their heads point in the direction in which the needles were inserted (Fig. 4). The position of the radon tubes is marked by heavy lines (Fig. 5).

Six platinum needles having a wall thickness of 0.5 mm. were allowed to remain in the tongue from Oct. 23 to Oct. 31. Five of these needles contained two tubes of radon, each 15 mm. long, placed in tandem, and one needle contained one tube of radon. The length of the total radiating focus amounted to 16.5 cm. The initial charge was 15.05 mc. The residue was 4.14 mc., the dose given, therefore, 12.91 mc. destroyed.

present (1927) we rely on radical block resection of the area in which suspected or positive glands are present. This is followed by radium therapy at a distance of 5–8 cm. from the skin, if histological examination of the removed glands corroborates the diagnosis of cancer.

3. The third method of radium therapy consists in creating easier access for the application of radium by a preceding surgical operation. This so-called radium surgery was thus named and has been applied for the past fifteen years by Dominici and his school. More recently, it was again suggested by Bayet and his collaborators (1923–1924). The method may have a future in some localizations of cancer which cannot be cured in any other way. At the Radium Institute we employ it only for the treatment of cancers of the nasal fossae and maxillary sinuses where we consider it the method of choice (Hautant, Monod and Verger, 1926). As much of the invaded area of the superior maxilla as possible is resected first. Radon-containing capillaries in tubes of 1 mm. platinum wall thickness encased in rubber are then placed in the cavity thus created. The radium tubes are maintained at the desired distance from the tissues by gauze packing which remains in place for several days. Ordinarily the unpleasant complication of radionecrosis of the maxilla can thus be avoided. The results of this method of treatment from the beginning of 1920 up to March, 1924 follow.[1]

Six of 18 patients thus treated were considered cured when reviewed December, 1927. Two of these had been treated in 1920, one in 1921, one in 1922 and 2 in 1923. Two other patients died of inter-

[1] These statistics will be brought up to date in the near future to include treatments given up to December 31, 1927. In the last three years the results seem to have improved considerably.

FIG. 6. Arrangement of needles in the treatment of a cancer of the left border of the tongue.

The posterior extremities of the needles have been sutured to the mucous membrane and the "safety threads" collected into a strand which comes out of the mouth at the commissure of the lips.

Note 1. It is preferable to tie the two threads 5 or 6 mm. away from the eye of the needle so as to prevent the knot from interfering with the complete insertion of the needle under the mucous membrane. The needles then do not project above the surface of the tongue and do not interfere so much with the comfort of the patient.

Note 2. In Figure 6 the needles have been inserted and sutured to the mucous membrane by means of a small curved needle. At the time of removal, the suture is cut between the knot and the mucous membrane and the needle withdrawn by the "safety thread" which is shown gathered under a piece of adhesive plaster.

A colored thread may be used to suture the needles in place. This differentiates it more readily from the white safety thread and helps to prevent losing the needles in the tissues.

current disease while the neoplasms seemed to have been cured; one of them was a case of eighteen months', the other of ten months' standing. One further patient died of cervical gland metastases while the primary localization remained cured. The 9 remaining patients died from local recurrence.

c. *Surface Radium Therapy.* Pioneer radium therapists treated skin cancer by the application of one to two radium tubes or plaques directly against the diseased surface after the interposition of some rubber or gauze. This primitive method has been supplanted by the placing of numerous radium-bearing tubes of equal strength on the external surface of specially constructed applicators which hold the radium at the desired distance from the skin. It is important that this focus skin distance is maintained throughout the applicator. The radiating focus must follow the inequalities of the surface of the body which is being irradiated. This can be obtained only by a molded applicator which is especially prepared for each individual case and fitted exactly over the part to be irradiated. Molded applicators are, from this standpoint, superior to the so-called rigid packs, the form of which is fixed and not adapted to each individual case. The material from which molds are made must be pliable during the molding of the form, and rigid when the mold is finished. It must maintain its rigidity when in contact with the body for days, as some irradiations take six to eight days of continuous exposure. It must be free from metal so as not to emit objectionable secondary rays. These prerequisites are all found in the "Columbia" paste developed in 1922 by my associates Drs. Esquerra, Monod and Richard at the Radium Institute. It consists of beeswax, paraffin and powdered wood, is plastic when heated and rigid when cold; lends itself easily to the construction of molded applicators, does not become deformed and does not emit secondary rays. The height of the mold varies with the depth of the neoplasm to be irradiated. Its lateral size depends upon the lateral extent of the growth.[1] Radium-bearing tubes are fixed to the outer surface of the mold, so that a radiating surface is created, at the desired distance, which is parallel with the surface to be irradiated, and which facilitates a fairly homogeneous field of radiation throughout the neoplasm. This may be verified in laboratory experiments by measuring by means of a small ionization chamber. Platinum tubes with a wall thickness of 0.5 to 1 mm. are used. They contain 5–10 mg. of radium element in cells of 15 mm. length. These tubes are interchangeable as they are of equal strength (Regaud and Ferroux, 1920). An example of this

[1] Tubes, the radium content of which may be expressed in whole numbers 2, 5, 10, etc., are convenient for those radium therapists who have retained the nomenclatures in milligram-hours. If one prefers to follow the publication of Debierne and Regaud, 1914, 1915, Regaud and Ferroux, 1919, and quotes the doses in millicuries-destroyed as is done in France, one will choose the contents of radium element of 1.33 mg. (10 microcuries destroyed per hour or μ cd/h), 3.33 mg. (25 μ cd/h), 6.66 mg. (50 μ cd/h), 13.33 mg. (100 μ cd/h).

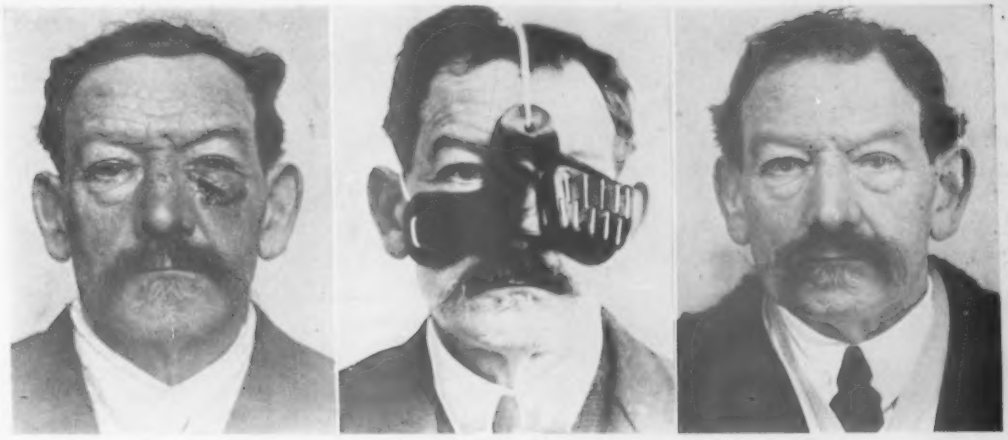

Fig. 7. Fig. 8. Fig. 9.

Figs. 7, 8 and 9. An epithelioma of the infra-orbital region treated with the aid of a wax mold.

M., infiltrating epidermoid carcinoma of the infraorbital region measuring 2.4 × 4.5 cm.

Treatment (March, 1922). The mold is made of one layer of Columbia wax, is supported on the bridge of the nose leaving the right eye open and is held in place by tape which is tied at the back of the head. The thickness of that part of the mold which lies directly over the lesion and supports the radiating surface, is increased to 2 cm. by the addition of a second layer of wax. This second layer measures 16 cm. square and on it are placed 47.75 mc. of radon distributed in ten platinum tubes of 1 mm. wall thickness. After a continuous application for seven days, there remained 13.89 mc. of the original charge. In other words, a dose of 33.86 mc. destroyed had been given. Healed completely two months after treatment. No evidence of disease when examined in March, 1928.

Fig. 10. Fig. 11.

Fig. 12. Fig. 13.

Figs. 10, 11, 12 and 13. Example of treatment of an epithelioma of the skin with the aid of a molded wax applicator with a window.

St. M., squamous cell epithelioma of the skin of the forehead with sebaceous evolution of the cells; dimensions 7.5 × 6.5 cm. Treatment in February, 1926. One layer of Columbia wax 10 mm. thick molded over the affected region with a window corresponding to the lesion. This opening was closed by a piece of wax measuring 105 cm. square. To its outer surface were fixed twenty-four tubes each containing 6.66 mg. of radium element. The tubes were of 1 mm. platinum each, and gave off 50 microcuries destroyed per hour. The mold was worn for several hours a day, during eight consecutive days, until a total of 93.6 millicuries destroyed had been given. Healing was complete one month later (Fig. 13). Complete healing; verified Jan. 27, 1928.

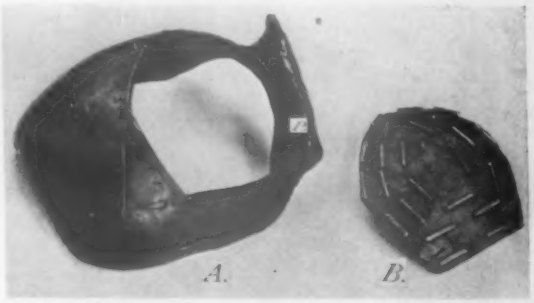

Fig. 14. Mold used in case represented in Figures 10–13.

A. Wax mold with window. At P a layer of lead 2 mm. thick covered with wax for partial protection of the face against the radiation from above.

B. The wax obturator with its radium tubes.

method of application in cancer of the skin is shown in Figures 7, 8 and 9.

In certain cases where immobilization of the mold on the skin is difficult and where absolute accuracy of application is desired, a window may be cut in the mold. The radium is then placed on the external sur-

face of a wax obturator and this plug is inserted to close the window. It may later be removed for inspection of the irradiated part without disturbing the mold (Figs. 10, 11, 12, 13 and 14). Molds for the treatment of skin cancers are usually made 1 cm. in thickness.

In thick, exuberant, cutaneous cancers the focus skin distance should be increased up to 2 or 5 cm. This favors a more equal depth dose throughout the thickness of the growth. The wax molds are protected laterally by 2 to 3 mm. lead shields. Figures 15, 16, 17 and 18 represent examples of such treatment.

In epidermoid cancers of the skin the method of using wax molds gives satisfactory results. These were reported at the Congress of Cancer held in Strasbourg (Regaud, 1923); 91 per cent operable and 40 per cent inoperable cases of that series were cured locally.

Several of the patients later died of cancerous metastases into the nodes of the neck, but the primary lesion remained clinically healed. Since that report, our results have considerably improved. The results have as yet not been brought up to date for all the localizations of skin cancer, but the following are our statistics for cancer of the lips and their commissures. Most of them had been treated by external radium therapy before December 31, 1925, and were reviewed December 31, 1927.

TABLE VII

CANCERS OF THE LIP OR ORIGINATING FROM THE LIPS
GENERAL RESULTS, 1919–1926
(Revised Dec. 31, 1927)

Years	1919	1920	1921	1922	1923	1924	1925	1926	Totals	Percentage
Cases retained for statistics	3	8	9	26	12	19	16	19	112	
I. *Operable cases*	0	2	2	12	9	14	10	13	62	....
A. Complete cure	..	1	2	10	9	13	10	11	56	91.9
B. Cure of primary localization of lip. Death from secondary adenopathy	..	1	..	1	..	1	..	2	5	....
C. Failure to cure primary localization of lip	..	..	..	1	..	..	..	..	1	....
D. Cure of the primary localization considered by itself	..	..	..	..	..	..	..	..	61	98.38
II. *Cases of doubtful operability*	0	2	2	7	1	3	3	4	22	....
A. Complete cure	..	1	1	3	1	3	3	4	16	72.7
B. Cure of primary localization of lip. Death from secondary adenopathy	..	1	1	2	..	..	..	..	4	....
C. Failure to cure primary localization of lip	..	..	..	..	..	..	..	..	2	.....
D. Cure of primary localization considered by itself	..	..	..	..	..	..	..	..	20	90.9
III. *Inoperable cases*	3	4	5	7	2	2	3	2	28	.....
A. Complete cure	..	1	1	1	..	..	1	..	4	14.2
B. Cure of primary localization of lip. Death from secondary adenopathy	..	1	..	..	..	..	..	..	1	.....
C. Failure to cure primary localization of lip	3	2	4	6	2	2	2	2	23	.....
D. Cure of primary localization considered by itself	..	..	..	..	..	..	..	..	5	17.8

In operable cases, cures of the primary localization were obtained in 61 of 62 cases, i.e., 98 per cent. If those with cancerous adenopathies are included, then there are 56 cases, that is, 92 per cent of cases cured.

In cases of doubtful operability, cure of the primary localization was obtained in 20 of 22 cases, i.e., 91 per cent, and a "complete cure," i.e., including cancerous adenopathies in 16, i.e., 72.7 per cent.

In operable cases, cure of the primary localization was obtained in 5 of 28 cases, and a "complete cure" in 4 cases, i.e., 14.2 per cent. The technique of application in cases of the lower lip is very simple. It was used first, I believe, by Janeway in

Fig. 15. Fig. 16.

Fig. 17. Fig. 18.

Figs. 15, 16, 17 and 18. Example of treatment of a thick exuberating carcinoma with the aid of a wax mold at a distance of 7 cm.

Bl. Vegetating epidermoid carcinoma of the eyelids and conjunctiva, probably with extension to the tissues of the orbit. The eye has as yet not been perforated. Treatment in August, 1926. Mold of one layer of Columbia wax 1 cm. thick over the cranium, nose and right orbital region. A second layer of wax superimposed on cork columns over the orbital region so as to give a focal distance of 5 cm. and a rectangular radiating surface of 71.5 sq. cm.

A lead wall 3 mm. thick covered by wax was erected on the nasal side of the mold so as to protect the left eye. Platinum tubes of 1 mm. containing 6.66 mg. each and delivering 50 microcuries destroyed were used. The radium content remained the same throughout the treatment but their number varied. A total of 150 millicuries destroyed was administered in eighty-nine hours of exposure, of daily application for ten days. The patient was seen again several months after treatment. He was apparently cured. Unfortunately he was lost sight of following that.

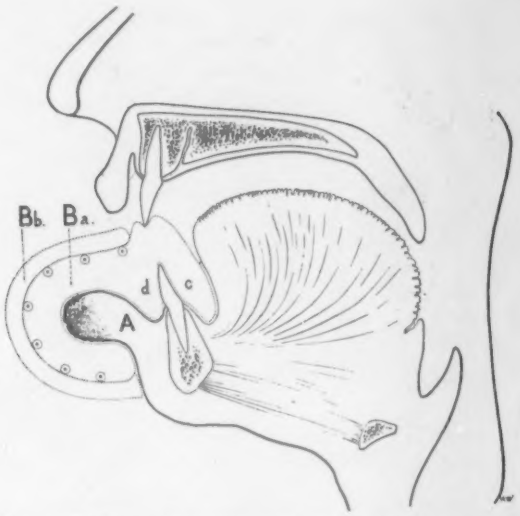

Fig. 19. Schematic representation of a median antero-posterior section of the buccal orifice showing the arrangement for irradiation of an epithelioma of the lower lip by means of a molded wax applicator.

A, cancer of the lower lip; Ba, a layer of wax 1 cm. thick molded around the inner and outer surfaces of the lip, and maintaining the latter slightly projecting forward; Bb, a layer of wax 0.5 cm. thick for covering the seven radium tubes. On transverse section there are seen surrounding the cancerous region, d, c, prolongation of the wax layer Ba, impinging upon the maxillo-labial and maxillo-lingual borders on one side, and the dental arch on the other side. The prolongation of the piece of wax is held between the teeth and helps to maintain the mold in place. A piece of cork is usually interposed between the upper lip and the wax so as to increase the distance between the radiating focus and the mucous membrane of the upper lip. When the incisor teeth are absent, the wax mold may be immobilized by molding it onto the gingival arch and by prolonging it laterally to the commissures of the lip. In all cases a bandage is used for maintaining and immobilizing the lower jaw.

1917. The lip is surrounded by a wax mold having radium tubes fixed to its outer surface. The mold rests on the dental arch and extends, if necessary, to the commissures of the lip. The upper lip is protected by increasing the distance between it and the radiating surface by a piece of wax, or in some other manner (Fig. 19).

The method of wax molds is also useful in the treatment of cancerous localization of medium depth, e.g., cancers of the breast and their gland metastases, cancers of the pharynx and larynx, cervical gland metastases, inguinal glands, etc. The thickness of the mold varies from 6 to 10 cm. according to the depth of the area to be treated. The size of the radiating surface may attain 100 or even 200 sq. cm. Rigidity of the mold is preserved as follows: two wax plaques 1 cm. thick are molded one after the other over the area to be treated. The first mold is in contact with the skin, while to the outer surface of the second are fixed cork columns of 2 to 6 cm. height. On these corks a third and sometimes a fourth layer of wax is superimposed which conforms to the contour of the area to be treated. A layer of wax is molded to form the lateral walls and the rigid box is ready for use. Radium tubes having a filtration of 1 mm. platinum are fixed to the outer surface of the mold. They are arranged

FIG. 20. Irradiation of the region of the pharynx and superior and median carotid gland in a case of carcinoma of the right tonsillar region with adenopathy.

The wax mold is carried by the patient with the head extended and somewhat rotated to the left. During the irradiation the mold is maintained in exact approximation to the affected region by elastic tapes. These tapes have been removed to permit a clearer view of the mold.

on the surface according to its form and the curvature of the radiating surface, so as to obtain as homogeneous a field as possible. Several decigrams of radium are necessary for this method of application on account of the focal distance. The lateral radiation beyond the field to be treated is taken care of to a certain degree by the erection of lateral walls consisting of several layers of lead having a total thickness of 5 to 6 mm. (Figs. 20, 21 and 22).

The molds, as mentioned earlier, are analogous to the blocks and packs used at the Memorial Hospital, New York, but have the advantage of being adapted to the form of the affected part, and are especially made for each individual patient. The radiating surfaces are placed parallel to the main portal of entry and permit greater precision of application than rigid rectangular packs. These molded packs may be kept continuously in place for eight to ten days with comparative comfort to the patient. Treatments of such duration are quite usual at the Radium Institute. The molds may be removed and replaced without fear of deforming them. When the mold is large and heavy, it is usually worn for a number of hours daily and replaced after the patient has had a rest for several hours. When the applicator is smaller and lighter, this is unnecessary. The method of applying hollow wax molds for deeper cancers has been perfected and standardized by my collaborator, O. Monod. We have lately been substituting radiation from a radium container mounted on a stand in place of heavy molds. This does away with the problem of weight and pressure and facilitates the successive irradiation of different patients with the same supply of radium in the course of one day.

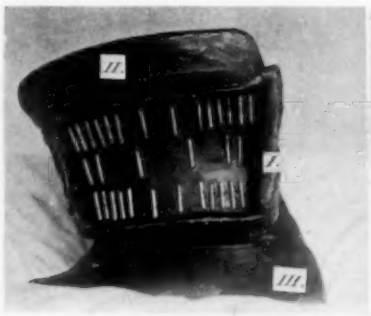

FIG. 21.

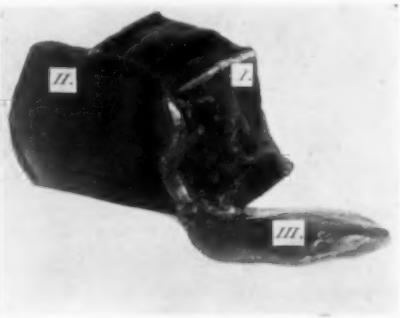

FIG. 22.

FIG. 21. The same mold as in Figure 20 seen from its focal surface.

I. Lead wall covered by wax and projecting 3 cm. above the "radiating" surface. II. The cervical part of the mold. III. The supraclavicular portion of the mold. It is partly hidden by the pillow on which it has been placed.

FIG. 22. The same mold as in Figures 20 and 21 seen from its cutaneous surface. I, II and III, same as in Figure 21.

After numerous failures with the treatment of neck gland metastases, we have arrived at the following method as being the most satisfactory at present (1927). We do a radical neck dissection, cleaning

out all visible glands, when there are glands present suspected of being malignant in cases of cancer of the skin and lip. In cases of cancer of the mouth such a resection is undertaken even when palpable glands are not present on account of the more frequent invasion of glands in these cases. My collaborator, Dr. J. Roux-Berger (1927), has perfected the technique for this operation. Application of radium on wax molds to the affected area follows the operation only if histological examination of the removed glands shows them to be cancerous. We believe that this combination improves the results of resection, and is preferable to the use of surgery alone. Final judgment on this question will have to be deferred until statistics of numerous cases histologically proved and treated by surgery alone, or in combination with radium therapy are available for comparison. If radium therapy is then shown to play an important part in the efficacy of this treatment, an attempt to do without surgery will be undertaken.

D. *Radium Therapy at a Distance.* In external radium therapy of deep cancers further progress has been made during the past few years by the use of special applicators holding several decigrams or even grams of radium element or equivalent quantities of radon 10 to 15 cm. away from the skin. This method has been in use at Kelly's Clinic in Baltimore, and the Memorial Hospital, New York, for some time. Certain innovations in the method of application, used at the Radium Institute of Paris lead me to present this subject here. The employment of apparatus containing one or several foci of radium, the radiation of which is directed and limited laterally by a tubular lead enclosure has been suggested by Lysholm (1923), Stenström (1924), Mallet and Coliez (1925), Sluys, and Kessler (1925). The disadvantages of these ingenious arrangements are that: the narrow cylindrical or conical form of the beams emitted from the apparatus does not favor the increase of the depth dose by scattered radiation. Only part of the entire radius of radiation, from each individual portion making up the radiating focus, is utilized since the opening for the beam is narrow. There is, therefore, a loss of radiation and the total yield is not economical. More important than these considerations, however, is the point that narrow portals of entry are incompatible with homogeneous irradiation of an extensive neoplastic zone, as precise firing at an invaded area is laborious and illusionary. These considerations led my collaborators, R. Ferroux, O. Monod, M. Bruzau, and myself (1925–1926) to adopt the method of irradiation through large portals of entry and a wide opening for the radiating focus.

Figure 23 represents our first apparatus. The stand was adopted from an roentgen tube stand. This is still very convenient for a container of several decigrams up to 1 gram of radium.

In our second model (Fig. 24) which has been used in our service since the beginning of December, 1925, we have adopted a charge of radium of 4 grams and a filtration equivalent to 1 mm. of platinum, a focus skin distance of 10 cm. and a radiating surface of approximately 150 sq. cm. This apparatus is especially suited for the treatment of cervico-uterine cancers complicated by extensive invasion of pelvic connective tissues. For irradiation of the true pelvis we usually employ six to eight portals of entry through which we crossfire the neoplastic zone amounting to a total of about 100 per cent of the epidermicidal dose.[1]

Due to the multiplicity of the entrance fields, this depth dose may be administered without any other cutaneous symptom except a slight erythema followed by pigmentation and dry desquamation.

The patient and his surroundings are protected against the unwanted lateral and back radiation by a cupola of lead the wall thickness of which, as used by us, is 6 cm. This adds considerable weight to the apparatus, ours weighing more than 80 kilograms, and necessitates a special method for its suspension and adjustment. The following are some of the details of our apparatus (Figs. 24, 25 and 26).

[1] The epidermicidal dose is the one which is necessary and sufficient to destroy only the epidermis. After the shedding of the epidermis, there is a superficial ulceration which goes up to the cutis,—selective radioepidermititis (Regaud and Nogier, 1913). This has the appearance of an ulceration produced by a vesicant. This biologic standard is preferable to the so-called skin erythema dose. The shedding of the epidermis is a benign lesion of certain duration, and one which may be appreciated with precision. Erythema, on the other hand, is a functional symptom of great variability and cannot be defined so accurately.

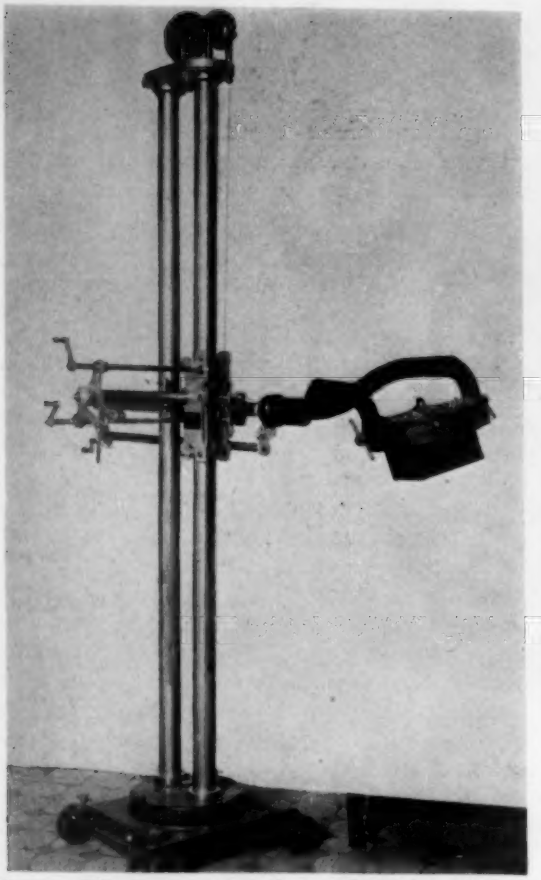

FIG. 23. The first apparatus for irradiation at a distance with greater quantities of radium used at the Radium Institute of Paris.

This apparatus has been discarded as it was felt that the 2 cm. lead wall did not offer sufficient protection from the radiation.

The 4 grams of radium are distributed in 80 tubes each containing 50 mg. These tubes are arranged in four groups of 20 at the four angles of a flat rectangular box made of brass measuring 135 × 110 mm. The radium tubes have a wall thickness of of 0.5 mm. platinum, and the brass of the box furnishes additional filtration so as to make the total the equivalent of 1 mm. of platinum. Attached to the radiating surface of the box is a localizer. This consists of 2 cm. lead wall surrounding and limiting the radiating surface; it is covered laterally by wax, and has a top of a 1 cm. wax plaque which forms the contact with the irradiated skin surface. The wax is used for absorption of the secondary rays of the lead.

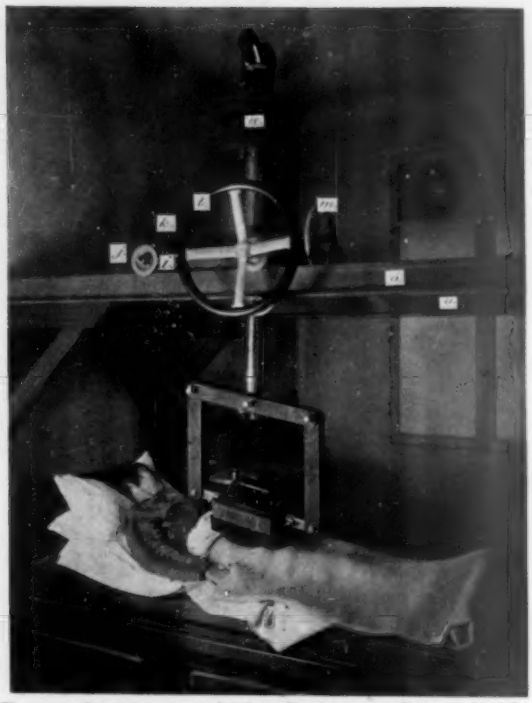

FIG. 24. Arrangement for irradiation at a distance with a focus containing a large quantity of radium. View of the entire apparatus.

The lead box is swung on steel trunnions between the sides of a parallelogram suspended from a cart which can be moved on a platform. All movements of the apparatus are accomplished with facility and precision by means of a ratchet and pinion arrangement. The apparatus may be immobilized in the position chosen by a screw clamp.

Electrometric measurements of the radiation emitted from our pack at 16 cm. focus skin distance, by Bruzau and Ferroux (1927), have shown that 28 to 30 per cent of the surface dose reaches 10 cm. below the skin if measurements are made within the limits of the field of direct radiation. The calculation and representation of depth dosages in this field of radiation are facilitated by the fact that the isodose surfaces are nearly plane and essentially parallel with each other.

It is evident that to carry out correctly the method described several different types of apparatus are necessary which may be adapted to individual treatments and localizations. When daily treatments are given lasting several hours, the patients

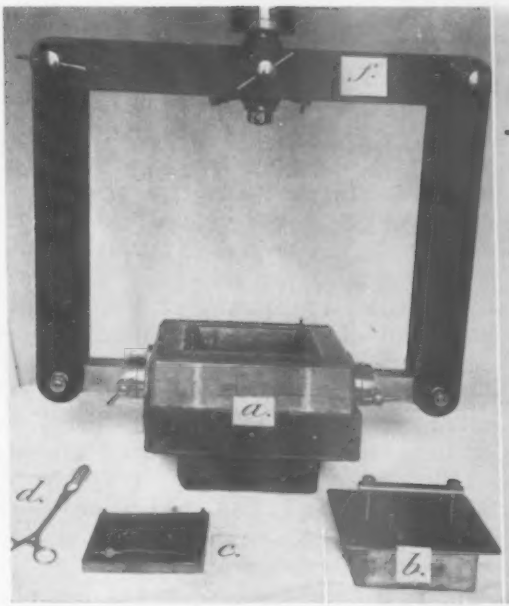

Fig. 25. Detail of one part of the arrangement represented in Figure 24.

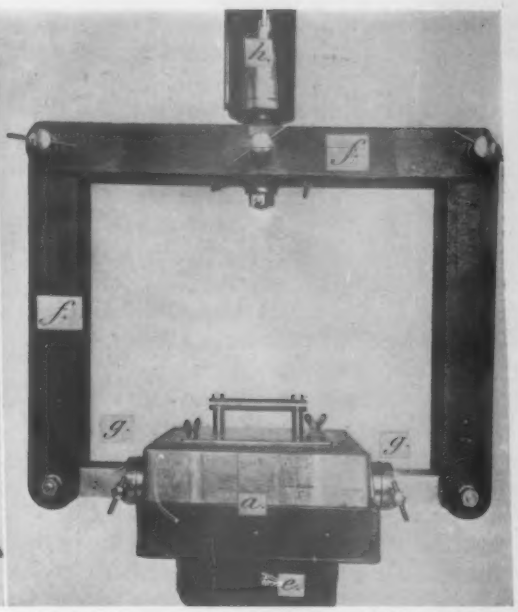

Fig. 26. Details of the lead box containing the radiating surface.

(*a*) Box containing the radiating focus. The lateral walls are of lead 6 cm. thick. (*b*) Lead covering of this box. (*c*) Thin rectangular brass box, containing radium tubes. It measures 135 × 110 cm. (*d*) Forceps for grasping plaque *c*. (*e*) Localizer. This consists of a lead wall, 2 cm. thick, covered by wax. (*f*) Hinged parallelogram which permits the box *a* to be inclined in any desired direction. (*g*) Trunnions on which the box *a* may be turned around its main axis. (*h*) Arm suspending the focus from cart *i*. (*i*) A movable cart which can be moved in horizontal and perpendicular planes on the rollers *j* and *k*. (*j-k*) Rollers. (*l-m*) Turn wheels for moving the cart. (*n*) Counter-weight for steadying the box *a*. (*o*) Rails.

may be comfortable by lying on pillows, and they support the treatment without difficulty.

The routine treatment for cancer of the cervix uteri with bilateral invasion of the pelvic connective tissue consists of fifty to sixty hours of irradiation over six to eight portals of entry and is given during a period of two to three weeks.

Radium therapy at a distance from the skin has been tried principally for the treatment of cancer of the uterine cervix at our Institute for the past three years. This disease offered opportunity for study of the comparative biological advantages of roentgen and radium rays acting under similar conditions, as the result of treatment by other methods are well known. My collaborators, R. Ferroux and O. Monod, and I announced our preliminary results in 1925. They were encouraging, but we are reserving final judgment for the time when definite proof will be available, as we are cognizant of the scientific, moral and industrial interests attached to the results of our experiment. At present we feel that radium is superior from the biological standpoint. Manipulation of the apparatus is easier than the one for roentgen rays. The expense of radium is very great, but it is not very much more than that of roentgen rays, providing the radium is made to work continuously. The cost will not be prohibitive if final results show radium to be considerably superior to roentgen rays.

PART II

SOME BIOLOGIC PRINCIPLES OF RADIOTHERAPY

It is evident that progress in the technical management of radioactive foci is of great importance. Appreciation of the deeper biologic principles, that is to say, the histo-physiological mechanism of the action of radiation on living tissues, however, is of still greater importance. We have learned a great deal on this subject but there remains still more to be found out. I

have had occasion to mention the importance of the following factors a number of times:

1. Equal irradiation of tissues and filtration play an important rôle when homogeneous radiation is attempted. Dominici called attention to this basic fact twenty years ago.

2. It is preferable to employ selective cyto-lethal radium therapy, i.e., penetrating radiation purified by filtration, a radiation which is able to destroy very radiosensitive cells without, at the same time, causing serious lesions in the general tissues (connective tissue, muscle, blood vessels, etc.) (Nogier and Regaud, 1908).

3. The time of treatment should be prolonged to a definite limit, so as to make radium therapy of some cancers more efficient without markedly increasing the dose (Regaud, 1922, *b* and *c*).

4. If non-lethal doses of radiation are applied at frequent intervals over long periods of time, normal tissues are sensitized and cancer tissues become resistant (immunized to radiation) (Delbet, Mocquot, Herrenschmidt and Mocq, 1914, Nogier and Regaud, 1914, Regaud 1920, *a*; 1922, *a*).

5. The radiosensitiveness of the basal mother cell layer of cancer cells should be utilized when the dose is planned. This layer is much more radiosensitive than the generations which follow it (Regaud and Blanc, 1906), Bergonié and Tribondeau, 1906; Regaud 1923 and 1924, *b*).

A great deal of progress in the radiotherapy of cancer is due to the recognition of radiophysiologic properties of cancer which will now be considered:

A. The unequal radiosensitivity of different cancers, and the correspondingly varying value of radiotherapy in these histological varieties.

B. The direct and indirect action of rays on cancerous tissues.

C. The superiority of the biological action of gamma rays over the action of roentgen rays.

A. When progress in radiotherapy of cancer is mentioned, the neoplasms usually referred to are cancers of the skin, mouth, uterine cervix and one or two other localizations. On the other hand, relatively little progress has been made in the radiotherapy of cancer of the breast, the prostate, urinary tract, the salivary glands, or cancers arising from the epithelium of the gastrointestinal tract, sarcomas, etc. While it is possible to prognosticate success from radiotherapy in a certain proportion of cases of the first group, cures by this method are exceptional in cases of the second group.

Cure of the primary lesion may be expected in the majority of epitheliomas arising from stratified epithelium of the skin, the orifices of the body and the mucous membranes covered with squamous epithelium, if the following favorable conditions prevail:

1. If the neoplasm has not been immunized against the effect of radiation by previous treatments.

2. If deep microbial infection is absent and reduction of the radiosensitivity of the neoplasm as well as the likelihood of grave complications arising from the infection is negligible.

3. If the extent and depth of the invaded area does not necessitate the irradiation of too great a volume of tissue and thus favor the risk of general intoxication from absorption of toxins from the destroyed tissues (radio-intoxication).

4. If the situation and extent of the tumor does not necessitate severe radiolesions or visceral perforation after absorption of the neoplastic tissues.

Limited success has been obtained with radiotherapeutic treatment of cancers of the upper air and alimentary passages on account of such local difficulties as those just mentioned. "Sterilization" of laryngeal cancers is easy, and a good proportion of them may be cured. Necrosis of the cartilaginous portion of the laryngeal structures, however, is a serious complication which cannot always be avoided and causes the death of some of the patients. The difficulty with cancer of the esophagus is its deep localization, necessitating irradiation through the thorax, and its proximity to important organs into which perforation occurs easily when the thin wall of the esophagus has been invaded. Extension into regional glands is an additional obstacle which frequently occurs. These

difficulties, however, depend upon the anatomical situation and not upon the histology of the particular cancer. In general, it may be said that cure of epidermoid cancer by radium therapy is possible only when difficulty of access or local complications do not interfere. Failure is not due to inherent properties of the neoplastic tissues. It should be emphasized that epidermoid cancers may be cured by selective radium therapy, i.e., by inhibition of the basal cell layer of the cancerous tissues without severe lesions of the general tissues, i.e., connective and vascular tissues which surround and penetrate the tumor. Unfortunately, this does not hold true for other pathologic varieties of cancers. For them, we cannot use selective radium therapy and we cure them only rarely and with great difficulty. This difference may be illustrated by a comparison of two cancers arising from neighboring organs: An adenocarcinoma of the rectum and an epidermoid carcinoma of the cervix uteri. The first mentioned cancer may be cured only in exceptionally favorable cases while the cancer is small, and only by caustic radiotherapy; the second type is curable in a large proportion of cases even when its size is more extensive, frequently after it has become inoperable, and this may be accomplished by selective radiotherapy. At the Radium Institute of Paris we have been able to cure cancers of the cervix uteri[1] using external roentgen and radium therapy alone, yet we have not been able to cure a single case of adenocarcinoma of the rectum by the same method. It is to be emphasized that this comparison does not apply to intracavity radium therapy in these two cancers. Access to the entire extent of a cancer of the rectum is more difficult than is the case with cancer of the uterus. If, however, results of external roentgen and radium therapy in these two cancers are considered, this objection disappears as their anatomical situation in the pelvis is quite similar when viewed from the standpoint of external radiotherapeutic technique. It then becomes evident that the inherent properties of the cancer tissues themselves, their structure, their mode of reproduction and their cell life are factors of the greatest importance which determine their response to the action of radiation.

Here are other striking examples:—(*a*) Two small cancers of the skin having the same size and situation, one is epidermoid and heals easily, the other is a nevus cancer and never heals except by massive destruction. (*b*) An epidermoid and an adenocarcinoma of the cervix uteri; they may have the same clinical appearance, so much so that one cannot distinguish them one from the other. It is comparatively easy to cure the epidermoid cancer by selective radiotherapy, while cure of the adenocarcinoma may be effected only with great difficulty or not at all.

We know something about the relation existing between the activity of tissue reproduction and its radiosensitivity. Unfortunately, this does not account in a satisfactory manner for the difficulty of sterilizing by irradiation such cancers as an adenocarcinoma of the rectum, of the cervix uteri or of nevus carcinoma of the skin.

B. *Direct and Indirect Effect on Cancer Cells.* This vast and complex problem is important to the radiotherapist and forms a much discussed subject among radiophysiologists. Some, and I am one of them, think the essential phenomenon is direct action of the rays on the cell. The vessels, connective tissues, and leucocytes are only of secondary, late and inconstant importance. Others, whose viewpoint I respect, believe that there is an additional indirect action on the cell from hypothetical products arising in the nutrient stroma. Finally, there are those with whom I cannot agree, who think that the action of radiation on cancer cells is principally indirect; that is, that it produces changes in vessels, collection of leucocytes in the connective tissue, modification in organs of internal secretions and their hormones, and that the mechanism of radiation effect is intimately connected with the defense

[1] Neumann and Coryn (1924) published a report of cured cases of cancer of the rectum situated low. The tumor was completely exposed surgically and then treated by radium puncture with needles filtered by 0.5 mm. platinum. My collaborators, Monod and Roux-Berger, using similar technique (unpublished results) were able to obtain only temporary regressions. Their tubes were filtered with 1 mm. platinum. The only cases which they cured were those in which a complete surgical removal of the irradiated tumor was possible. Ordinarily radium puncture transforms cancers of the rectum into a fibroneoplastic block in which histological examination discloses the persistence of cancer cells. This proves that this procedure is not selective and is insufficient.

of the entire body against the cancerous process.

(*a*) Histological changes cannot be noted in vessels, connective tissue and leucocytes preceding an effect on cells when the action of roentgen rays and gamma rays on normal tissues is studied. One is forced to recognize that modifications of the vascular and connective tissues are secondary, late and are only in connection with a liquefaction and cicatrization process. Following the same line of reasoning, it seems possible that after a cell has been injured by the direct action of rays its life may be terminated by the additional effect of indirect action of the rays.

J. B. Murphy believes that normal tissues are more radiosensitive than cancerous tissues. He studied the relation of irradiation with roentgen rays to cancer grafts, especially the rôle played by lymphocytes in the changes following roentgen irradiation. I had the privilege of discussing this problem with Dr. Murphy and he emphasized the possibility of a difference in the essential mechanism of radiation between normal and cancer cells. This view, however, is not supported by histologic study of irradiated normal tissue (Regaud, 1925, Regaud and Lacassagne, 1927).

The epidermis of the human skin may easily be completely and selectively destroyed by a single exposure of roentgen rays. The first histological modification which may be noted is a disappearance of the basal cell generative layer by autolysis. While this lesion appears to be slight, it nevertheless marks the death of the epidermis. The elements of the derma are not affected. Erythema (the seat of which is in the vessels and in the connective tissue) and the death of the generative cell layer of the epidermis are, in my estimation, two independent phenomena. The local abundance of leucocytes is not noted until later. In studying histologic changes following irradiation of testicles and ovaries one does not see any evidence of participation of leucocytes, vascular or connective tissues. A further contradicting illustration may be found in a study of salivary glands, and smooth or striated muscle which have been vigorously irradiated. Because of the slight radiosensitivity of these structures, "reactions" of the vascular and connective tissues should be easily noted here. Such evidence, however, is totally lacking.

It is improbable that normal and neoplastic tissues undergo fundamentally different radiophysiologic processes. The unlimited and disorderly multiplication of cells may confer on cancer certain peculiar radiophysiologic properties but does not eradicate the characteristics inherited from the tissues from which the cancer originated, and with which it remains in relationship. It may be assumed that the essential radiophysiologic properties are the same for normal and neoplastic tissues. Explanation of the action of radiation by experimental studies of grafted tumors in small animals is perhaps open to other objections also, but I will not discuss them here.

(*b*) If the mechanism in irradiation of cancers depended mainly on the visible morphologic reaction of the vessels and of connective tissue as was stated by Ewing as recently as 1926, then we would not observe such great discrepancy in the behavior of cancers having the same anatomical situation but different histology.

The distribution of vessels and structure of the connective tissue does not differ much in a cancer of the rectum and cancer of the uterine cervix, in an adenocarcinoma and in an epidermoid cancer of the uterine cervix, in an epidermoid cancer and in a nevus cancer of the skin. Yet there is a marked divergence in the response of these cancers to radiation which cannot be explained on the basis of differences in vascular and connective tissues. One is forced to admit that this varying response of different cancers to radiation, all other conditions remaining the same, must be assumed to be connected with inherent differences in structure and radiophysiologic properties of the epithelial neoplastic tissue.

It is possible that the point of immediate attack of radiation is the cell itself and at the same time the medium in which it is placed. The cancer cell may thus be directly affected by the rays and indirectly

poisoned by a toxin produced from the vascular and connective tissue stroma which supports and nourishes the cancer. I realize that this hypothesis lacks proof. It will explain, however, the results of the experiments of Murphy and his collaborators, on the one hand, and, on the other hand, the fact that certain vital properties of the vascular and connective tissues (Regaud, 1924, *a*) are slowly but permanently modified by the rays.

It must be admitted that this hypothetical modification of pericellular plasma is not supported by an appreciable change in structure.

c. *Superiority of Radium.* It is certain that roentgen rays and gamma rays of radium have in a general way the same mode of action on living tissues. Nevertheless, gamma rays of radium are undoubtedly *more selective* in their action than roentgen rays. If normal or neoplastic tissues are exposed to roentgen rays or gamma rays, under similar conditions, it will be noted that the latter produce the death of radiosensitive cells with less injury to more radioresistant cells, such as blood vessels and connective tissue, and that they cause a lesser degree of general intoxication than is produced by roentgen rays in spite of a similar effect on cells.

Up to twelve years ago, I believed that this selective action on the more radiosensitive cells was a question of specificity of the wave length. I have not abandoned this theory completely, and it cannot be considered as disproved (Regaud and Nogier, 1913). It is maintained by numerous authors, e.g., by Russ in England (1923), by Dognon in France (1925), etc. If there are peculiarities of action of radiation in relation to specific wave length, it seems that these peculiarities are comparatively small. The biologic effect of roentgen rays or gamma rays is principally, if not exclusively, a question of absorption as pointed out by Guilleminot (1919), Wood (1924) and other authors.

Transformation of radiation in matter has been studied by physicists, and the purity of action of gamma rays is partially explained by these studies. I do not feel competent to discuss this difficult field but can base my opinion more on biological experience. I believe that in the future builders of roentgen apparatus will pay as much attention to obtaining more penetrating radiation as they do now to creating greater quantitive output, in spite of the fact that will be a long while before roentgen rays are produced which are as penetrating as gamma rays. We may have decagrams of radium at our disposal in the future instead of the milligrams of the pioneer days, or decigrams of today which must be purchased at high cost. When this time arrives a revolution in radiotherapeutic methods and renewed progress in the treatment of cancer will take place.

It is difficult to predict whether we are approaching a considerable lowering of the price of radium, or whether such a reduction is improbable. Remarkable progress is being made in roentgen therapy. Thus, it is possible that by the time a lowering of the price of radium and further experience with it will have proven its superiority, progress in the technique of roentgen therapy will nullify the significance of this advantage and render radium therapy at a distance a useless procedure. For this reason, the opinion expressed in the first lines of this article is justified, namely, that roentgen rays and gamma rays of radium should not be separated from each other in scientific research and practical application bearing on the treatment of malignant neoplasms. It is impossible to predict at present which of the two will be given preference in the future.

SUMMARY AND CONCLUSIONS

1. The progress of radiotherapeutic methods cannot be judged by temporary regressions but only by statistics of cures based upon indisputable data, which are periodically brought up to date and followed over a sufficiently great number of years.

2. Radium therapy through natural cavities of the body cures with regularity only epidermoid carcinoma of the cervix uteri, and only when the cancer has not as yet extended far beyond the limits of the uterus, i.e., cases of the so-called first and partly of the second stage. In cancers which are more extensive this procedure can be used only as an addition to irradia-

tion from an external source. In other localizations of cancer, intracavity radium therapy usually does not result in more than temporary diminution of the tumor.

3. Homogeneous irradiation from radiating sources used for interstitial radium therapy may best be obtained by numerous foci of weak individual strength, with filters which permit the penetration of gamma rays only. Radium puncture with removable platinum needles which may be inserted directly into the tissues seems to be the simplest and the least evil of these. At the Radium Institute of Paris radium puncture has been reserved for the past few years to a small number of localizations, especially cancer of the tongue.

Radium surgery we consider as a procedure which should be used only exceptionally; we employ it principally for the treatment of massive cancers of the facial bones, especially antrum cases.

4. Surface radium therapy, as carried out at the Radium Institute of Paris, is applied with the aid of wax molds which permit fields of radiation with regular isodose surfaces.

Series of interchangeable radium tubes constitute the radiating surfaces on the external aspect of these supporting molds. The radiating surfaces may thus be varied in form, dimensions and strength. This procedure gives excellent results in epitheliomas of the skin. When it becomes necessary to have focal distances over 3 cm., hollow wax molds are employed so as to make them lighter in weight. The efficacy of this method has as yet not been determined in cancers which extend 5 cm. below the surface or more; especially in cancerous adenopathies.

5. For distances of application which are 6 to 8 cm., the great size and potent charge of the radiating focus necessitates protection of lead walls, the weight of which cannot be supported by the patient. Radium therapy at a distance which then becomes necessary calls for arrangement for the support of the radiation focus and its protecting screen. An apparatus containing 4 grams of radium has been employed at the Radium Institute of Paris since 1925. Its radiating surface measures approximately 150 sq. cm.; the focal distance is 10 cm., and 1 mm. platinum is used as filter. The large-sized opening for the beam permits each part of the radiating focus within this surface to have a great radius of its radiation utilized. Large entrance fields on the skin facilitate the concentration of uniform radiation intensity in extensive neoplastic zones. The isodose surfaces are practically plane and the volume dose can be easily determined.

6. The varying radiosensitiveness of cancers is of the greatest importance. Progress in technique of radiotherapy has brought striking evidence of the inequality in sensitiveness of various cancers by eliminating certain causes of error.

The only cancers which have been cured regularly by radium therapy are cancers originating from epidermoid structures. The number of successful treatments is reduced by anatomico-topographical difficulties of some localizations, for instance, in cancers of the esophagus.

Adenocarcinomas are in general more radioresistant than the neoplasms just mentioned. At the Radium Institute of Paris we have been unable to cure, by selective radiotherapy, adenocarcinomas of the rectum or cervix uteri except in a few rare instances.

7. The principal radiation effect on cancer cells is not an indirect injury. Variations in the abundance of leucocytes, and lesions in the vasular and connective tissues of the irradiated areas are inconstant and late. Lesions of radiosensitive cells are early and constant. Direct cyto-lethal action of radiation is, therefore, the essential phenomenon in the treatment of cancer.

It cannot be assumed that there exists a fundamental difference between normal and cancer cells from the standpoint of radiophysiology.

8. Gamma rays of radium have an undoubted biologic superiority over our present day roentgen rays. This superiority results from a selective action which is especially defined in its biologic effects on radiosensitive cells. Nevertheless, it is possible that the inferiority of roentgen rays is only temporary and that increase in their penetration power will reverse this relation.

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Vol. XXI, No. 1

THE TREATMENT OF EPITHELIOMA OF THE PENIS BY RADIOTHERAPY AND ELECTROCOAGULATION*

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EPITHELIOMA of the penis forms from 1 to 3 per cent of all cancers in males (Paget Billroth); it occurs most frequently in the fifth, sixth, and seventh decades of life, but has been observed at eighteen years of age. Chronic inflammation, phimosis and syphilis are given as the chief causes. The initial lesion is usually regarded as a simple wart, and appears as an eroded papule, thickening of the epithelium or as an ulcer. Papillary tumors of the glans are nearly always malignant (Ewing[6]).

Lymphatic extensions occur through the superficial vessels to the inguinal nodes and through the deep lymphatics and along the dorsal vein to the pelvic nodes (Ewing). The inguinal nodes are commonly involved and often on both sides. Kaufmann[9] found the inguinal nodes free in only 8 out of 48 cases. Permeation along the dorsal lymphatics is the rule, and continuous cords have been traced up to the groin, pubes, and even to the umbilicus, and the liver is a favorite seat of metastasis.

The disease usually develops slowly, especially in cases which remain papillary and escape ulceration. The lesion can be seen and felt by the patient from the beginning. There is no part of the body that is seen and handled more frequently or that can be examined more easily. Such observation is possible at every urination. There is, therefore, no good excuse for this disease reaching an advanced stage before coming under medical care.

As a matter of fact, if phimosis and syphilis are cured whenever found, and all other lesions of the penis treated expertly as soon as found by the patient, there will probably never be any cancer of the penis. This ideal situation demands education of the male population, and that all physicians master the diagnosis and treatment of all benign or suspicious lesions, or that they realize their limitations and at once refer the patient to an expert.

TREATMENT

Nothing can be more important to the individual patient than the treatment, since the great majority of patients already have advanced cancer when they first apply to the expert for treatment, and metastasis has taken place in from 32 to 83 per cent according to different authors (Küttner[11] 32 per cent in 60 cases, Shivers[14] 40 per cent in 5 cases, Barringer and Dean[2] 40 per cent in 56 cases, and Kaufmann[9] 83 per cent in 48 cases).

Kretschmer[12] believes that the diagnosis of carcinoma of the penis is synonymous with amputation of the penis, and this seems to be the general attitude of the surgeon. Föderl[7] (40 cases) advises against removal of the inguinal glands except in very young patients with fast growing tumors.

Wilensky,[16] Hadda,[8] and Dax[4] have reported some success with radical emasculating operations. This technique has never been popular and seems to have been generally abandoned.

In cases of cancer of the penis, as in other cancers, an occasional case runs an unusually favorable course, but it is very unwise to depend upon such results. Barney[1] observed 11 cases with no treatment in which one patient lived eleven years without operation, but at no time without cancer.

Taylor[15] reports a case in which he amputated the penis without removing the lymph nodes in the sixth year of the disease. The patient remained well for ten years (evidently the lymph nodes were not malignant). Lymph nodes may of course become enlarged due to secondary infection of the ulcer, but it is dangerous to assume that they are not malignant, for such inflammatory processes open the way for an extension of the malignant process. The end-results from surgery alone in advanced cases have been most discouraging.

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Barringer and Dean[2] urge preoperative irradiation in all cases, particularly if there is obvious metastasis, and advise dissection only when there is failure of complete regression of the lymph nodes following such irradiation. O'Crowley[13] treated 2

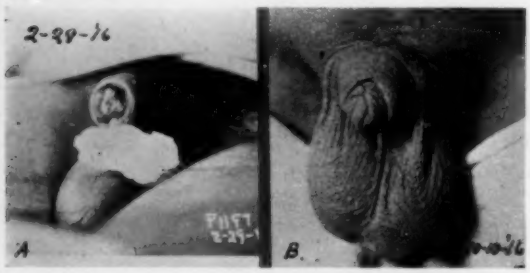

FIG. 1. Case 1. A. Epithelioma of the glans penis, duration one year. Tumor hidden under the prepuce; lymphatic glands enlarged. B. Treated by amputation by means of electrocoagulation and postoperative roentgen treatment over the groins; well, 1928.

cases with colloidal lead, but radium was also used, and subsequently amputation became necessary. In 1921 Corbus[3] reported a successful result in a case of a prickle cell carcinoma of the penis treated by electrodesiccation and radium. Kelly and Ward[10] report one case successfully treated by removal of the local lesion by means of electrodesiccation and removal of an enlarged gland in the groin with the endotherm knife.

In superficial lesions of cancer of the penis, without inguinal metastasis, Dean[5] reports 5 out of 6 cases alive and well one and a half, three and a half, four, and five and a half years, respectively. These cases were treated with surface irradiation only. When the local tumor was extensive without metastasis, amputation with preliminary and postoperative irradiation shows 21 out of 30 cases living three months to five years.

In this disease as in cancer elsewhere in the body, it is difficult to make comparative statistical studies because no two cases are really alike. We therefore will make brief reports upon 11 cases treated by irradiation and electrocoagulation, and in which we think we have obtained results which are superior to those obtained by mere surgical removal.

CASE REPORTS

CASE I. Mr. S. C. S., aged forty-six, was referred May 26, 1916, by Prof. E. LaPlace and Dr. W. S. Hoffman. He had an epithelioma involving the entire glans and extending onto the dorsum, involving one-third of the penis; duration one year. There were palpable lymph nodes. The penis was amputated by means of electrocoagulation, at the middle of the corpora cavernosum, after a preliminary course of irradiation given over the penis and groin. This was followed by further irradiation to the limit of skin toleration during a period of three months. He is well twelve years after treatment (Fig. 1).

Remarks. Prof. LaPlace considered this case inoperable surgically. By amputating at the middle of the corpora cavernosum the patient at no time had any difficulty with urination and except for a period of about two months has been working for twelve years.

CASE II. Mr. C. W. F., aged seventy-six, was referred Jan. 3, 1919, by Dr. Samuel Barbash, with an epithelioma involving the entire glans. He was given a preliminary course of roentgen treatment over the penis and pelvis by daily doses during six days. The penis was amputated by electrocoagulation at the junction of the middle and proximal third, on Jan. 8, 1919. He was given a second course of roentgen treatment during the last of January. He remained well for seven years and died of pneumonia.

CASE III. Mr. E. M. C., aged fifty-seven, was referred for treatment Aug. 31, 1920, by Dr. Peter F. Moylan. The patient had an epithelioma of the glans covering an area 3 cm. in diameter. There were no lymph nodes palpable. We treated the patient locally by surface application of radium, with 100 mg. of radium, filtered through 0.5 mm. silver and 1 mm. rubber and arranged as a plaque over the lesion for three hours, and 50 mg. in 1 mm. gold and 0.5 rubber in the urethra for two hours. One series of roentgen treatments was given over the pelvis in November, 1920. On Dec. 13, 1920, he was free from evidence of disease. In March, 1921, there was some induration and evidence of recurrence. We gave roentgen treatment over the entire penis and pelvis, and on April 25, 1921, the penis was amputated by electrocoagulation. This healed and was reported well by Dr. Moylan, but the patient became insane and died on July 4, 1921. The cause of this insanity is not known. This patient lived less

than a year after beginning treatment, but at the time of his death, he was free from any evidence of disease about the penis or pelvis.

Case IV. Mr. C. C., aged forty-nine, was referred for treatment April 13, 1921, by Dr. W. Lathrop. The prepuce had been removed four years previously on account of a growth. A papule formed on the glans two years before the patient came to us. When we first saw him the entire glans was involved by a cauliflower growth the size of a hen's egg. The tumor involved one third of the penis, with induration extending backward on the dorsum to the pubis. Metastatic nodules were palpable in the groin and pelvis. Radium was applied locally and deep roentgen therapy was applied over groins and pelvis. Three months after beginning treatment all palpable glands had disappeared, and the local disease had been reduced to about 10 per cent. In five months from beginning of treatment, pain, swelling, and necrosis developed in the glans, probably due to the large amount of local irradiation. On Sept. 26, 1921, the penis was removed at its base by electrocoagulation, under general anesthesia. Microscopic study by Dr. Eugene Case still showed evidence of squamous cell carcinoma in the glans. Locally he had 3,800 mg-hr. of radium element at from 3 to 10 mm. distance over different areas of the tumor, filtered through 0.5 mm. silver and 1 mm. brass. On Oct. 11, 1927 this patient reported himself well and working every day, now seven years after treatment (Fig. 2).

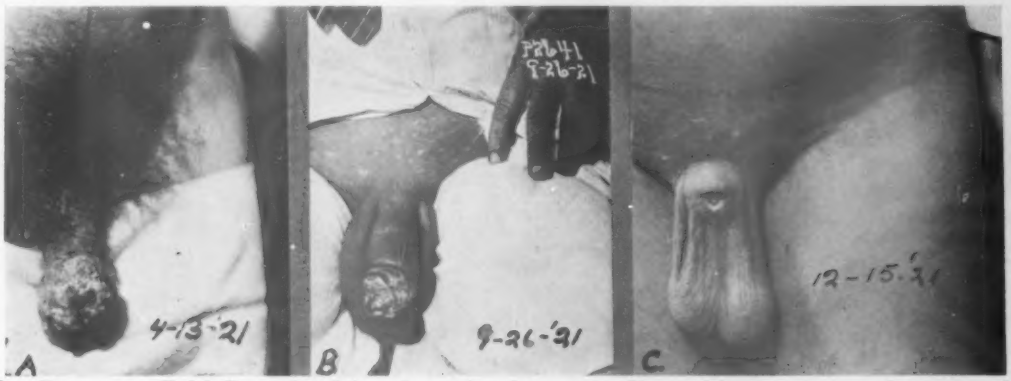

Fig. 2. Case IV. A. Epithelioma involving the entire glans penis. Circumcision on account of new growth four years previously. Tumor mass about the size of a hen's egg; enlarged lymph nodes in both groins. B. Showing disappearance of about three-quarters of the tumor tissue under local applications of radium, with disappearance of the lymph nodes in the groin. There was then a fibrosis and edema developing in the anterior two-thirds of the penis, which made it necessary to do an amputation by electrocoagulation. C. Shows result after amputation and seven years since.

Remarks. Of special interest in this case, was an intense headache which developed at about the time that the wound had healed in November, 1921. Roentgen examinations of the cranial bones and sinuses showed nothing abnormal. Eye grounds were examined by Dr. Maxwell Langdon and found normal. It was evidently not due to carcinoma, and gradually disappeared during two years.

The previous patient became insane at about the time the wound healed. No autopsy was obtained. Taking these two cases together, one with headache only and the other with mental symptoms, some direct association may be indicated.

Fig. 3. Case V. A. Epithelioma of the glans penis, duration one year. Section was then removed by Dr. Erdmann and found to be squamous cell carcinoma. B. Shows complete disappearance of the tumor tissue under radiation treatment. Later, a secondary degeneration developed for which amputation was advised but which was refused.

Case V. Mr. H. A. D., aged fifty-six, was referred by Dr. W. S. Erdman on July 9, 1921, for treatment of an epithelioma 2 cm. in diameter involving the glans, with metastasis palpable in the groin, beginning one year

previously as a papule at the corona. Severe pain led him to see Dr. Erdman. A section removed by Dr. Erdman showed squamous cell carcinoma. He was treated locally with radium, and over the groins and pelvis with roentgen therapy to the limit of normal tissue toleration during two months. After three months all evidence of disease had disappeared (Fig. 3).

A year after beginning treatment, he developed a recurrent ulcer at the corona. This healed under applications of zinc oxide ointment. Three years after beginning treatment he developed a necrotic ulcer, which we believed to be due to the endarteritis caused by the radiation. Therefore we advised amputation by electrocoagulation. The operation was refused, and necrosis continued. The patient died of uremia early in 1925, about four years after beginning treatment. He received locally radium element, 1240 mg-hr. in six applications during two months, at a distance of 33 to 15 mm., and filtered through 1 mm. brass. This is less radiation than we have given to other patients who have apparently recovered (Case VIII).

Remarks. This patient was cured of cancer, but developed a secondary degeneration and died about four years later. We still believe that if he had submitted to amputation by electrocoagulation he would probably be living.

CASE VI. Mr. J. McA., aged seventy, was referred by Dr. F. X. Jones on March 29, 1923, for treatment of extensive recurrent carcinomatous nodules in the operative area of the left groin and perineum. In 1922, the patient had been treated by a wash for three months and by radium for six months. On Feb. 15, 1923, he had an amputation of the penis, with a complete resection, and a perineal opening, and resection of the metastatic glands in the left groin, by Dr. Hershey Thomas at the Samaritan Hospital. On March 29, 1923, he was admitted to the service of Dr. F. X. Jones at the Misericordia Hospital. At this time, red and fixed nodules were palpable throughout the operative field varying from 0.5 to 2 cm. in diameter. Dr. Jones considered the case totally inoperable and we all considered his case practically hopeless. The disease was treated entirely by high voltage roentgen rays by the saturation method at our private institute. He was given a total of only 120 per cent of an erythema dose in each of four fields. The disease had completely disappeared in two months. *He has remained well for five years.*

Remarks. This case is of interest because of the rapid and extensive recurrence, despite an extensive and otherwise successful operation. The disease disappeared rapidly under radiation treatment, probably because it was of a type which is especially sensitive to radiation. Not infrequently we find that rapidly recurring tumors respond to irradiation very well. There is however, always danger of distant metastasis. Therefore, the radiation treatment should be instituted as soon as it is recognized.

CASE VII. Mr. J. E. V., aged thirty-seven, was referred by Dr. W. E. Andrews on March 11, 1924, for treatment of a recurrent epithelioma of the glans penis, following local cauterization at the operation for phimosis three months previously. Two months previously it had been destroyed again by electrocoagulation followed by roentgen treatment.

When we saw him the entire dorsum of the glans was involved by an indurated recurrent epithelioma. A section was removed and the entire indurated tissue destroyed by electrocoagulation. Dr. Case reported squamous cell carcinoma. This wound never healed. Seven months after the electrocoagulation, a section was again removed, but showed no evidence of cancer. Fifteen months after beginning of our treatment, we removed another section which showed squamous cell carcinoma Type 3 (Broders). This was followed by amputation by electrocoagulation. The wound healed and on Sept. 16, 1925, he was free from any visible or palpable disease. On Feb. 17, 1926, we found evidence of metastatic disease in the perineal region but none in the stump of the penis. This disease increased and he died on Oct. 29, 1926. The patient had 1080 mg-hr. of radium element applied locally over the glans at a distance of 3 mm. during three months, filtered through 1 mm. of brass. He had a full erythema dose of deep roentgen rays applied over the pubes and groin, given in three doses during one month.

Remarks. This case was a failure. The growth had been incompletely destroyed twice previously, and we were dealing with the third recurrence. The radium retarded the disease locally, but did not completely destroy it in spite of a necrotic effect. No glands were palpable at any time, and only one erythema dose of roentgen rays was applied over the anterior pelvis. None was given in the perineum, to which the disease

finally extended. It would seem to be advisable to treat the perineum in future cases.

Case VIII. Mr. A. T. G. T., aged forty-nine, was referred by Dr. F. J. Dever on March 21, 1925, for treatment of leucoplakia of the glans penis of one year's duration. A section studied by Dr. E. Case showed only leucoplakia (Wassermann reaction was negative, Dr. Kolmer).

The leucoplakia was destroyed by electrocoagulation, radium was applied locally and the wound healed. On Aug. 15, 1927, he returned with a recurrence of leucoplakia. A section was again removed and found to be squamous cell carcinoma.

On Oct. 31, 1927, a second recurrence of an indurated ulcer was found. Amputation was advised but was refused. A section was again removed and the local disease destroyed. This section was found to be non-malignant. On Feb. 14, 1928, the patient appeared to be well. In addition to the electrocoagulation he had received locally 2109 mg-hr. of radium.

Remarks. This patient had a leucoplakia during one year. The diagnosis of leucoplakia was confirmed by microscopic diagnosis. A recurrence of leucoplakia showed carcinoma by microscopic examination. A recurrence of an indurated ulcer showed carcinoma. He is apparently free from disease three years after beginning treatment. We have never failed to cure leucoplakia in the mouth by electrodesiccation combined with radium treatment. We think this case should be permanently cured.

Case IX. Mr. I. G. B., aged sixty, was referred by Dr. G. O. O. Santee, on June 18, 1925, for treatment of an epithelioma of the penis of four years' duration. It involved the entire glans. There were no palpable lymph nodes, despite the large growth, the long duration, and a very fat patient. We immediately removed the penis at its middle and followed this by high voltage roentgen rays given over a period of three months, amounting to a total of 300 per cent. The patient is well three years afterward.

Remarks. This case was probably of the less malignant type. The tumor was a squamous cell carcinoma, but could not be definitely typed. The patient was very stout.

Case X. Mr. J. N., aged fifty-six, was referred by Dr. G. Baringer Slifer on Oct. 14, 1926, on account of epithelioma of the glans penis of three months' duration. There were palpable lymph nodes in the left groin. A section was removed which showed squamous cell carcinoma, Type 2 (Broders); 167 per cent of an erythema dose of high voltage roentgen rays was given over the groins and pelvis in two weeks, resulting in complete disappearance of the induration in the groin.

Radium element (3,862 mg-hr.) was applied to the glans within a period of ten months, without causing complete disappearance of the disease. Therefore, on Sept. 16, 1927, eleven months after beginning treatment, under local anesthesia we amputated the penis at its base by means of electrocoagulation. Further microscopic study by Dr. E. Case showed the specimen to contain some cancer tissue of squamous cell, Type 3 (Broders). We then applied to the stump of the penis 1,420 mg-hr. of radium element in three applications, at a distance of 0.5 cm. with 1 mm. brass filtration.

His wound healed without difficulty and he has remained well nine months since the operation. He is happy and went to work two weeks after the operation.

Remarks. This case began as a leucoplakia. It did not respond to extensive treatment by radium. The glands in the groin did respond to high voltage roentgen therapy. The amputation following irradiation seems to be a success.

Case XI. Mr. J. F. S., aged fifty-one, was referred by Dr. C. H. D. Shivers, for treatment of an ulcerating recurrent and metastatic carcinoma of his right groin. The penis had been amputated for carcinoma, and metastatic glands resected December, 1925. In February some roentgen therapy was given, but the cancer continued to grow. It was thought that highly filtered gamma rays might possibly do some good, and this was tried, but without avail.

Remarks. This case cannot be classed as the treatment of epithelioma of the penis, for we gave no treatment until after there was extensive ulcerating recurrence in the groin, where metastatic lymph nodes had been resected.

SUMMARY AND CONCLUSIONS

1. This study is based upon a review of 10 cases of carcinoma of the penis, and one case in the terminal stage of ulcerating carcinoma in the groin, following amputation and resection.

2. Of the 10 cases, 9 are free from any gross evidence of cancer twelve and seven years, eleven months, seven, three and a half, five, zero, three, three, and one and three-fourths years after beginning treatment.

3. In the cases which we treated with radium alone we did not cure the primary disease. Roentgen treatment would be expected to do even less.

4. The high voltage roentgen treatment was effectual in controlling the palpable lymph nodes, and in causing the disappearance of recurrent nodules in the perineum and groin (5 years).

5. It would seem that one cannot depend upon irradiation alone to cure the primary cancer of the penis, except in the very early lesions.

6. If enough radiation is used to cure the disease in an advanced case, there is likely to be a secondary necrosis due to an endarteritis caused by the irradiation.

7. The apparent cure of 90 per cent of the cases by a combination of amputation by electrocoagulation and irradiation would seem to be sufficient to recommend this form of treatment.

8. It has been observed also in cancer elsewhere that irradiation is at times more effectual on the lymph nodes and the recurrent nodules than on the primary lesion.

9. The permanent cure (5 years) of an extensive, rapidly recurrent case, would indicate that irradiation should be used as postoperative treatment in all cases.

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ABSTRACT OF DISCUSSION

Dr. H. H. BOWING, Rochester, Minn. My experience with this condition has been in treating the inoperable carcinomas, that is, massive infiltrating tumors of the glans penis with extensive involvement of the inguinal glands. As a rule, the primary lesions respond to treatment, while the metastatic lesions do not respond so well, chiefly because it is impossible to apply adequate treatment. Learning of Dr. Pfahler's results will lead me to persist in the treatment. In treating the primary tumor, we use the crossfire method, applying well-filtered radiation well under the erythema dose, interposing a dental mold to maintain distance. I feel certain that we should avoid the caustic effect usually produced by partly filtered radiation. I recall one case of a massive primary involvement in which the lesion was so extensive that it was impossible to make out the glans penis, but within two months or so the gross appearance of the structure had returned to normal. This was a very striking result; however, the involvement of the inguinal glands progressed. For the cases under discussion, palliation is all that can be expected and with this in mind, irradiation offers a great deal since it will eliminate much suffering.

DR. J. D. MORGAN, Philadelphia, asked whether attempts had been made to use the 4 gram pack in this condition, and requested Dr. Burnam to state whether they had had any experience in Baltimore where such a pack was available.

Dr. CURTIS F. BURNAM, Baltimore, Md., stated that so far as he knew the heavy irradiation by means of the cylinder or pack had not been unusually favorable in these cases.

DR. PFAHLER, in closing, stated that all of the glandular and metastatic areas had been treated by high voltage roentgen therapy.

Having only a gram of radium he could not use the packs mentioned. Two of the cases that responded locally to irradiation later developed secondary necrosis. He did not think this arose from any local caustic effects, but was due to an endarteritis, the result of the total irradiation, and not a single dose. The total irradiation must always be taken into account and the possible secondary effects therefrom considered. On the basis of his observations he believed that the proper procedure was to inform the patient, except in a very early lesion, that he must count on an amputation of the penis, and he considered that the best method of amputation was by electrocoagulation.

RADIOACTIVE DETERMINATION ON POST-MORTEM SPECIMENS TAKEN FROM ONE EXPOSED TO RADIOACTIVE MATERIAL OVER A PROLONGED PERIOD

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REITTER and Martland[12] refer to 6 cases on record where death was attributed to the fact that the individual was exposed to rather large quantities of radioactive material over a considerable period of time. The manner in which a person may be so exposed resolves itself into two forms: (1) Exposure to large quantities of the more penetrating type of radiation where the radioactive material is hermetically sealed in some suitable applicator. In such cases it is obvious that the chance of finding any radioactive material in the various organs of the body is nil. Any changes that have been found to occur[5,9,10,11,15] must have been produced during the time of exposure and cannot be continuous as would be the case were the radioactive material actually contained in the system. Persons who are about an emanation plant or engaged in the handling of large quantities of hermetically sealed radioactive preparations may be so exposed.

(2) In the other form of exposure the radioactive material may be taken into the system either through the lungs or alimentary tract. Perhaps the more common way of so introducing the material is by inhalation of the gaseous disintegration products, although it may also enter the system through dust in the air whereby it may again reach either the lungs or alimentary tract. Regardless of whether the radioactive material is taken into the system in the gaseous or solid form, unquestionably the greater part of it is secreted within a short time leaving only a small proportion of the total fixed in the various organs. The effects of either thorium or radium emanation so remaining in the system cannot be of long duration as the life of thorium emanation is about ten minutes and that of radon (radium emanation) thirty days. However, in the case of radium emanation the decay of the gaseous products results in the formation of solid products of very slow change, which give rise to the less penetrating types of radiation. Such solid products may remain in the system for an indefinite period of time.[1,2,3] Where radioactive material is taken into the system as small microscopic particles in the air, part of it at least will reach the lungs where it may be deposited in a manner similar to lead, which often results in what is commonly known as lead poisoning.[4,8] Radium and mesothorium in the human body have a strong tendency to form salts such as sulphates and carbonates, which are very insoluble,[7] consequently the amount which can be absorbed by the blood stream will undoubtedly be small. Persons engaged in the commercial production of radioactive preparations are often exposed to the gase-

ous disintegration products from high grade radium preparations as well as to radioactive dust particles, from ores which may be weak, or very active in character.

This report represents a study of the radioactive products found in the organs of an individual who had been exposed to radioactive dust particles and emanations over a period of nearly ten years. Inasmuch as we have not found a report of this nature on record it seems advisable to give an account of the experiments performed in some detail, together with the deductions that may be drawn therefrom.

The author acknowledges the co-operation of Drs. Reitter and Martland for supplying the following list of organs which were examined: liver, gastrointestinal tract, kidneys, heart, spleen, bone, right lung, and left lung. Table 1 gives the organs, their weight in a body weighing 160 pounds, the weight taken for examination, the dry weight of the specimen taken, and the calculated dry weight of the total organ. It may be stated that prior to examination for the radioactive elements the specimens were pretty well dehydrated but not charred to any extent.

TABLE 1

Organ	Wt. in 160 Lb. Body, Gm.	Wt. of Tissue Used, Gm.	Dry Wt. of Tissue, Gm.	Calculated Dry Weight of Organ, Gm.
Liver	1800	1200	200	300
Gastrointestinal tract		Entire		
Kidneys	300	300	90	90
Heart	300	250	33	40
Spleen	260	173	25	33
Bone	9800	150	20	1300
Right lung	....	...	51	75
Left lung	1400	933	25	37

Preliminary alpha-ray examination of the organs indicated little or no activity of the liver, gastrointestinal tract, kidneys, and heart; feeble activity of the spleen; and quite marked activity of the bone and lungs. The preliminary tests were followed by a series of careful readings and over a period of several weeks to insure the detection of the growth of any activity that might be taking place as a result of the material having been partially de-emanated at the time of incinerating. A special type of Wulf quartz fiber electroscope was used for making the tests and every precaution possible taken to avoid contamination or the introduction of other errors.

Liver, Gastrointestinal Tract, Kidneys, and Heart. A compilation of the readings made on several different dates clearly indicated that in the case of the liver, gastrointestinal tract, kidneys, and heart the quantity of radioactive material present was nil.

Spleen. In the case of the spleen there seemed to be definite indication that the material was slightly active. However, the quantity of radioactive material present was almost infinitesimal, in fact too small to be determined accurately, considering the amount of material present for experimental purposes. A rough estimate would indicate that the total activity was about one-fortieth that of the bone, the activity of which is given later.

Bone. Inasmuch as the bone gave a decidedly positive alpha-ray test, a careful and detailed study was made to ascertain, if possible, some idea of the quantity of radioactive material present as well as the specific radioactive elements. Systematic alpha-ray tests were made extending over a period of two months. It was noted from the start that there was a marked tendency for the activity of the specimen to increase for the first few minutes after it was placed in the ionization chamber of the electroscope, but after six to ten minutes an equilibrium was reached and the readings became constant. This increase amounted to as much as 50 per cent of the initial activity in some instances, and seemed to indicate the presence of members of the thorium series, which were later definitely established. Considering that the total activity was contributed by various members of the uranium and thorium series, it is difficult to express the readings in a concrete unit such as milligrams of radium element or its equivalent. However, by comparing with a standardized sample of a virgin uranium-bearing ore, taking into consideration the free emanating power of the ore, it is possible to get some idea of the number of alpha particles emitted per second. It is obvious that the value so

determined cannot be exact when it is considered that one is dealing with alpha rays from different sources and with different ranges, but the figures should give an idea of the order of magnitude, and that is sufficient for our purpose. The interpolation of the values as the number of alpha particles emitted per second will be made a little later, while for the present the activity will be expressed in terms of virgin ore containing definite percentages of uranium oxide. On this basis the maximum activity of the bone was comparable to the activity of a typical carnotite ore containing 2 per cent uranium oxide. It is of interest to note that the activity of the specimen showed a slight increase over a period of the first four or five weeks, which may be accounted for by a partial de-emanation of the specimen at the time of drying. The presence of members of the thorium series was definitely established by taking a specimen of the bone and de-emanating, that is, removing the gaseous radioactive products. The sample was then allowed to stand for ten minutes after which any emanation that might have formed in that time was drawn into a standard type of Lind emanation electroscope, and the rate of decay of the gas noted. By noting the successive number of net divisions over which the charged gold leaf moved in 54.5 seconds, the half-decay period of thorium emanation, it is obvious that its presence would be definitely established in the event that the number of divisions for each successive reading was one-half that of the previous reading. The results of two measurements made were as follows: Run 1:4.0 div., 2.2 div., 1.1 div., and 0.2 div. Run 2:3.2 div., 1.8 div., 1.0 div. This evidence definitely established the presence of members of the thorium series.

Radium determinations on the bone made by the emanation method, showed that it contained from 4.5 to 5.0 $\times$ 10^{-7} mg. of radium element per gram, which amount is equivalent to the radium contained in a typical carnotite ore assaying 0.15 to 0.17 per cent uranium oxide.

The following experiment was next performed with the hope of establishing the presence of members of the radioactive family classified as active deposit of slow change, Ra D, Ra E, Ra F. Such products might be deposited in the system by the decomposition of the gaseous products resulting in the formation of solid products of slow change, which are for the most part volatile at temperatures ranging from 500 to 1000°c. A small clean porcelain crucible was placed in the ionization chamber of an alpha-ray electroscope and the natural drift of the fibers noted, after which a definite weight of the bone was placed in the crucible and the drift of the quartz fibers again noted, thus enabling one to compute the drift due to the bone. The crucible and contents were then ignited over an ordinary but good Bunsen burner, after which an alpha-ray examination indicated that the activity of the bone had been reduced to practically zero, although the bulk of the material had not been greatly reduced. The crucible and contents were next ignited over a blast lamp after which no further change in the activity was noted. Measurement of the activity has been conducted over a period of two months and while there is a slight recovery of the initial activity, still it will be some time before the activity reaches that noted prior to heating. The experiment seems to fairly definitely establish that the total activity of the bone is contributed largely by the decay products of slow change, probably Ra F.

Thus it seems to be definitely established that the activity noted in the bone is made up of radiation from: (1) mesothorium and its decay products; (2) radium and its decay products of rapid change, and (3) radioactive products classified as active deposit of slow change.

Lungs. Specimens of the right and left lungs were prepared separately, consequently tests were conducted on each lung. It is of interest to note that the physical characteristics as well as the chemical behavior of the two samples were quite distinct. As seen from Table 1, the dry weight of the right lung was considerably greater than that of the left, which may be accounted for by the presence of much more cartilage. Inasmuch as both specimens of the lung tissue showed marked activity when examined with the alpha-ray

electroscope they were submitted to much the same type of tests as was the bone, the details of which have been given.

The critical examination indicated that the maximum activity of the left lung was equivalent to that of a virgin carnotite ore containing 2.50 per cent uranium oxide, and that of the right lung to an ore containing 1.40 per cent uranium oxide. Here again there was a marked tendency for the activity to increase during the first few minutes that the material was in the ionization chamber, indicating the presence of members of the thorium series. The activity measured after several weeks was also slightly higher than the original activity noted, again indicating that there had probably been a partial de-emanation.

The presence of members of the thorium series was tested for and established in precisely the same manner as in the case of the bone. The rate at which the emanation of short life decayed was determined by reading the successive number of divisions over which the gold leaf attached to the ionization chamber passed in 54.5 seconds. In the case of the left lung the values were: 17.0 div., 10 div., 5 div., 3 div., and 1.5 div. and in the case of the right lung, 8.0 div., 4.0 div., 2.0 div., 1.0 div., and 0.5 div. The curves plotted from these values are typical of the decay curve of thorium emanation.

Radium determinations by the emanation method indicated that the left lung contained 4.75 to 5.25×10^{-6} mg. of radium element per gram, which is equivalent to the quantity of radium contained in an ore whose uranium oxide content varies from 1.65 to 1.80 per cent. The specimen of the right lung contained 3.25×10^{-6} mg. of radium element per gram, equivalent to the radium in an ore assaying 1.10 per cent uranium oxide.

Ignition of the samples of the lung tissue did not dispel the activity as was found in the case of the bone. In fact the activity usually showed an increase after ignition, due to the fact that the bulk of the samples was reduced and consequently the radium exposed to the surface increased, whereupon the effective alpha radiation was also increased. This result is not at all anomalous when it is considered that a far greater percentage of the total activity is contributed by radium and its decay products of rapid change than in the case of the bone. Considering the quantity of radium found, together with the fact that there are also members of the thorium series present, it is obvious that little if any of the total activity can be attributed to the active deposit of slow change. It therefore appears that the total activity of the lung specimen can be accounted for by: (1) radium and its decay products of rapid change, and (2) mesothorium and its decay products.

Table II gives a summary of the data collected relative to the bone, right and left lungs. The number of alpha particles emitted per second was calculated by assuming that 1 gram of uranium oxide

TABLE II

	Bone	Right Lung	Left Lung
Dry weight	1300 gm.	75 gm.	37 gm.
U_3O_8 equiv. per gm	0.02 gm.	0.014 gm.	0.025 gm.
Total equiv. U_3O_8	26.0 gm.	1.05 gm.	0.92 gm.
Radium element per gm	4.75×10^{-10} gm.	3.25×10^{-9} gm.	5.0×10^{-9} gm.
Total radium element	6.2×10^{-7} gm.	2.44×10^{-7} gm.	1.85×10^{-7} gm.
Total No. of alpha particles emitted per second	2.1×10^{6}	8.5×10^{4}	7.5×10^{4}
No. of alpha particles emitted per sec. due to Ra inc. of Ra C	0.09×10^{6}	3.6×10^{4}	2.8×10^{4}
No. of alpha particles emitted per sec. due to meso. and the decay products of slow change (difference)	2.01×10^{6}	4.9×10^{4}	4.7×10^{4}
Equivalent quantity of radium computed from the total No. of alpha particles emitted per second	1.42×10^{-5} gm. 0.014 mg.	5.7×10^{-7} gm. 0.00057 mg.	5.1×10^{-7} gm. 0.00051 mg.

mineral emits 8.1×10^{-4} alpha particles per second,[13] and 1 gram of radium in equilibrium with its decay products, inclusive of radium C, emits 14.88×10^{10} alpha particles per second.

GAMMA RAYS

Thus far consideration has been given to the alpha rays only as a means of detecting as well as determining the approximate activity of the various specimens under investigation. However, an attempt was made to determine the activity by means of gamma radiation, but the activity of such samples as were active was too weak to arrive at any definite value in terms of milligrams of radium element or its equivalent. The tests were of value, however, in that the same specimens which showed activity by the alpha radiation, gave a very feebly positive test by the gamma radiation.

DISCUSSION

It is known that the individual whose organs have been examined was engaged in the refining stages of the commercial production of radium and mesothorium for a number of years prior to his death and must of necessity have been exposed to considerable quantities of the emanation as well as the solid preparations. A large part of this exposure could have been avoided had the proper precautions been taken, but the individual was negligent at times, though fully cognizant of the hazards connected with his vocation. The fact remains that he unquestionably inhaled emanation in varying quantities, and at times his work was of a nature where he might have taken small microscopic particles of the high grade salts into his lungs by means of the air breathed as a carrier. Let us see what would probably happen if particles of the high grade salts (chlorides, bromides, carbonates, and sulphates) were inhaled. In the case of the soluble salts such as chlorides and bromides, they would likely be converted to carbonates by the carbon dioxide in the air and that in the lungs, and upon deposition on the walls of the lung cells, to sulphates by the oxidized sulphur and sulphates carried by the blood stream. Consequently by the time the material could be deposited on the walls of the lungs it is quite probable that it would all be in the form of sulphates or radium or mesothorium. The solubility of such salts by the blood stream is exceedingly small, consequently only a very small fraction of the total quantity deposited could be carried throughout the system unless the microscopic dust particles were phagocytized by the histiocytes of the alveolar epithelium and endothelium, and finally gained access through their lymph sinuses to the blood stream. The radium and mesothorium found in the bone must have been carried there by one or the other of these courses, and due to the affinity of the bone for calcium and its replacibility by strontium and its chemically similar products were deposited.[6,14] How long material so deposited would remain fixed is problematical, but indications are that it remains there for a matter of months at least.

Now let us follow briefly the course of the emanation (gaseous disintegration products of radium and mesothorium) which was inhaled. As previously stated, the greater part of it would unquestionably be exhaled, with a small percentage of the total picked up by the blood stream and transported throughout the system. As the life of the emanation is short (maximum thirty days) it could not be effective over a long period of time. However, in its decay, it first forms products of rapid change followed by the active deposit of slow change, with a half-period of years in some instances. It is thus quite possible to trace how the active deposit of slow change, whose presence has been indicated, could have been deposited in the bone.

Assuming that the above satisfactorily explains the manner in which the radium, mesothorium and active deposit reached the bone, the experimental evidence bears out what might be expected in that the relative amount of the active deposit of slow change was large as compared to the amounts of radium and mesothorium. Had the solid preparations deposited in the lungs been soluble in the blood to a larger degree, the reverse might have been the case, whereupon the total activity might

have been predominantly contributed to by radium and its decay products, inclusive of radium C, and mesothorium.

The quantity of active deposit which can be deposited in the lungs must obviously be small considering that the time which a gaseous product remains in the lungs, as such, must be short. Here again the experimental evidence seems to bear out what might be expected in that the quantity of active deposit of slow change detected was small as compared to the quantities of radium and mesothorium.

Let us examine for a moment the types of rays which would be effective in the lungs and bone. Inasmuch as the active material in the lungs consisted primarily of radium and mesothorium of about equal proportions according to the alpha-ray comparison, there would also be present the usual beta and gamma rays associated with these compounds. However, the effects produced by the beta and gamma rays must have been very small in comparison with the alpha, even though their range is many times that of the alpha particle. Considering the very small equivalent quantity of radium found in the lungs, 0.001 mg., it is safe to say that any systemic effects the beta and gamma rays might have had were extremely minute. It seems quite probable that the alpha rays produced a definite effect on the system.

In the bone the active material was found to consist primarily of members of the active deposit of slow change, none of which give rise to gamma radiation. Two of the members emit beta rays, but very weak in nature, consequently their effect may be considered as nil. Here again, then, the only rays that need consideration, so far as producing any change in the human system is concerned, are the alpha rays.

To attempt to discuss the changes which these alpha rays might produce on the blood or other organs of the body is not within the scope of this paper. It is of interest to note that the total equivalent quantity of radium element found in the body examined was about 0.015 mg.

SUMMARY

1. It has been definitely established that:

a. The liver, gastrointestinal tract, kidneys and heart show no abnormal amount of radioactive material.

b. The spleen shows the presence of radioactive material in greater concentration than is normally expected.

c. The bone and lungs show marked presence of radioactive material.

2. The activity of the bone has been demonstrated to be due largely to the active deposit of slow change together with comparatively small amounts of radium and mesothorium. The actual quantity of radium has been determined and the equivalent quantity computed from the determination of the number of alpha particles emitted per second.

3. The activity of the lungs has been demonstrated to be due to the presence of radium and mesothorium. Here again the actual quantity of radium has been determined and the equivalent quantity computed from the determination of the number of alpha particles emitted per second.

4. The channels through which the radioactive materials may have reached the organs where found has been discussed.

5. The types of rays that may have been effective in producing systemic changes in the body examined have been discussed.

CONCLUSIONS

The quantity of radioactive material found in the body examined was hardly sufficient to produce the systemic changes which resulted in death. Any changes that occurred due to the effects of radium must have been accentuated by the inhalation of rather large quantities of emanation, the greater part of which was shortly excreted, or the exposure to the more penetrating type of gamma radiation from hermetically sealed preparations. Although it is known that the individual in question inhaled the emanation at various times and was exposed to the gamma radiation of rather high intensity, it is impossible to determine the amounts of either one of these exposures he received.

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ROENTGEN-ANATOMICAL STUDIES OF THE COLON IN PATIENTS WITH PULMONARY TUBERCULOSIS

BY

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THE aim of the studies here presented is to obtain eventually some light on two important questions: first, whether the colon shows by roentgenological methods any characteristics peculiar to tuberculous individuals; and second, whether certain anatomical features of the colon (viz., shape, position, peritoneal and topographical relationships) in those individuals in whom intestinal tuberculosis has at any time complicated the pulmonary lesion, differ from those in the uncomplicated cases.

In a previous communication the writers* outlined their method of investigation, which since has become a routine procedure in the roentgen laboratory of the Trudeau Sanatorium, and reported the anatomical data obtained by roentgenological methods in 150 patients with pulmonary tuberculosis. In the present paper records on an additional series of 150 patients of the Trudeau Sanatorium are presented, and the findings in the total number of 300 patients, 150 of whom were male and 150 female, are summarized. Most of the patients studied were between twenty and forty years of age. Only 14 (7 male, 7 female) were under twenty and 23 (12 male, 11 female) above forty, the youngest patient being fifteen and the oldest forty-eight years of age. It should be mentioned that all the data given refer, as

* Halpert, Béla, and Sampson, Homer L. A Roentgen-anatomical study of the colon on one hundred and fifty patients with pulmonary tuberculosis, Am. J. Roentgenol. & Rad. Therapy, 1927, xvii, 253–265.

before, to findings in the upright position and the roentgenograms mentioned are twenty-five hour films taken in the same position.

Although the data obtained so far are in many respects at variance with the current notions on skeletotopy (i.e., position of viscus in relation to skeleton) and syntopy (i.e., position of organs in relation to one another) of the abdominal organs, the writers feel that conclusions are not warranted as to the original problem until a sufficiently large number of cases have been studied and until similar data are available on an equal number of healthy, non-tuberculous individuals.

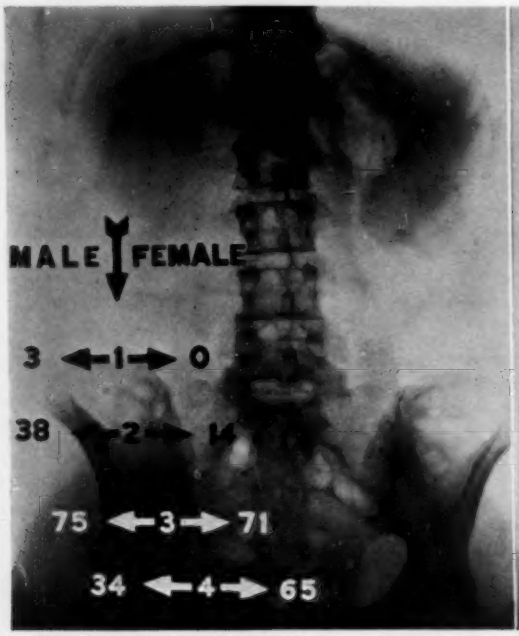

FIG. 1. Illustrates the position of the cecum in relation to the skeleton. The cecum was in the 1st position, i.e., near the crista iliaca in 1 per cent (3 male); in the 2d position, i.e., in the fossa iliaca in about 17 per cent (38 male, 14 female); in the 3d position, i.e., on the linea terminalis in about 49 per cent (75 male, 71 female); in the 4th position, i.e., in the pelvis minor in 33 per cent (34 male, 65 female).

FIG. 2. A part of the greater curvature of the stomach is seen below the level of the transverse colon.

Female, aged twenty-seven (No. 7256). Cecum: in the pelvis minor (i.e., in 4th position). Ascending colon: long, dextroconvex. Flexura coli dextra: at the level of the 3d lumbar vertebra; the two arms of the angle lay parallel for about half of the length of the ascending colon; presence of adhesions inferred. Transverse colon: cranioconvex; peak of convexity at the level of the 2d lumbar vertebra. The lowest point of the greater curvature of the stomach: below the level of the promontorium. Flexura coli sinistra: at the level of the 12th thoracic vertebra.

THE CECUM AND THE COLON ASCENDENS

It may be recalled that in our classification the cecum was in *1st position* if it lay on the crista iliaca or higher; in *2d position*, if in the fossa iliaca; in *3d position*, if on the linea terminalis (slightly above or below), and in *4th position*, if situated in the pelvis minor (Fig. 1).

The cecum was found in the *1st position*, i.e., near the crista iliaca, in 3 (all male), or 1 per cent of the 300 cases; in the *2d position*, i.e., in the fossa iliaca, in 52 cases (38 male, 14 female), or about 17 per cent; in the *3d position*, i.e., on the linea terminalis, in 146 cases (75 male, 71 female), or about 49 per cent; in the *4th position*, i.e., in the pelvis minor, in 99 cases (34 male, 65 female), or 33 per cent.

It is of interest to note that the cecum was situated in the pelvis minor almost twice as frequently in females as in males.

The ascending colon was dextroconvex in all cases in which the cecum lay in the 3d or 4th position; these groups comprised approximately 82 per cent of the total. In those in which the cecum occupied the 2d position (52 cases) the ascending colon was straighter.

According to length, the ascending

colon was classified as before into three groups: (*a*) average, (*b*) long, (*c*) short. If the hepatic flexure was at the level of the third or fourth lumbar vertebra (i.e., at L_3 or L_4) and the cecum in the 2d or 3d position respectively, the length was considered average. Deviation from this group was considered long or short respectively.

The length of the ascending colon was found *average* in 178 cases (88 male, 90 female), or about 59 per cent, *long* in 73 cases (30 male, 43 female), or about 24 per cent, *short* in 49 cases (32 male, 17 female), or about 16 per cent.

THE FLEXURA COLI DEXTRA

In 166 (80 male and 86 female), or about 55 per cent of the 300 cases, the hepatic flexure (flexura coli dextra) was situated at the level of the fourth lumbar vertebra (L_4); in 78, or 26 per cent, below (31 male, 47 female, all at L_5); and in 56, or about 18 per cent, above. Of those found above the level of the fourth lumbar vertebra 44 (30 male, 14 female) were at L_3, 11 (8 male, 3 female) at L_2, and one (male) at L_1.

In only 22 cases (13 male and 9 female), or about 7 per cent, did the ascending colon turn into the transverse colon at approximately a right angle. In all the other cases (278) the hepatic flexure was an acute angle. In 191 of these (94 male, 97 female) the first portion of the transverse colon lay parallel with the ascending colon: in 106 cases (61 male, 45 female) for half of the length or less, in 85 cases (33 male, 52 female) for more than half the length of the ascending colon. Out of the 191 cases in which the transverse colon lay parallel with the ascending colon for any distance, the presence of adhesions about the hepatic flexure was inferred in 157 cases (83 male, 74 female), or about 52 per cent.

THE COLON TRANSVERSUM

In all but 4 of the 300 cases, the transverse colon was *caudoconvex*. The 2 cases of the new series (one male, and one female) in which it was *cranioconvex* are shown in Figures 2 and 3. The bow described by the transverse colon was regular in 272 cases: in the balance, 28 cases (18 male, 10 female), its course was irregular. The irregularity occurred usually on the right half, near the hepatic flexure, or the middle of the transverse colon and was attributed, as before, to the coincidence of (1) an imperfect and irregular fusion of the layers of the greater omentum along the taenia omentalis of the transverse colon, and of (2) the presence of some additional but not necessarily pathological fusion of the peritoneal covering, forming connecting bands between parts of the colon.

The Position and the Relative Position of the Transverse Colon and the Greater Curvature of the Stomach.

In all but 5 cases (3 male, 2 female) the transverse colon was found at a lower level than the greater curvature of the stomach. The two lay *close and parallel* in 130 cases (81 male, 49 female), or about 43 per cent, *distant* in 165 cases (66 male, 99 female), or 55 per cent. Of the remaining 5 cases in which a part of the greater curvature of the stomach was seen below the transverse colon, 2 (one male, and one female) of the new series are shown in Figures 2 and 3.

Perfect fusion (1), *non-fusion* (2), *imperfect fusion* (3), and *irregular fusion* (4) of the layers of the greater omentum were judged, as before, by the relative position of the stomach and the transverse colon as seen during roentgenoscopic examination, during palpation and on roentgenograms.

(1) A *perfect fusion* was inferred in 107 cases (75 male, 32 female), or about 36 per cent; (2) a *non-fusion*, i.e., an absence of the so-called gastrocolic ligament in 107 cases (35 male, 72 female), or 36 per cent; (3) an *imperfect fusion* in 67 cases (30 male, 37 female), or about 22 per cent, and (4) an *irregular fusion* was deduced in 14 cases (7 male, 7 female), or about 5 per cent. The 5 cases in which the greater curvature of the stomach was seen below the transverse colon are, of course, not included in these figures.

The most dependent portion of the transverse colon was located above the level of the promontorium in only 62 cases (52 male, 10 female), or about 21 per cent. In the rest, 238 cases (98 male, 140 female),

or about 79 per cent, it was found below the level of the promontorium, 72 of which (13 male, 59 female) were even lower, i.e., near the level of the symphysis.

It is of interest to note that of the 62 cases in which the transverse colon was above the level of the promontorium 52 were males. Thus the transverse colon was found above the level of the promontorium in about 35 per cent of the males (38 at L_5, 8 at L_4, 5 at L_3, and 1 at L_1) and in only about 7 per cent of the females (7 at L_5, 1 at L_4, 1 at L_3 and 1 at L_2).

The lowest point of the greater curvature of the stomach was found above the level of the fourth lumbar vertebra (L_4) in only 11 cases (8 male, 3 female), or about 4 per cent (8 at L_3 and 3 at L_2). In the rest, or 289 cases, the convexity reached lower than the level of the third lumbar vertebra (L_3). It was found in 56 cases (45 male, 11 female), or about 19 per cent, at the level of L_4, in 125 cases (65 male, 60 female), or about 42 per cent, at the level of L_5, and in 108 cases (32 male, 76 female), or 36 per cent, below the level of the promontorium (Fig. 4).

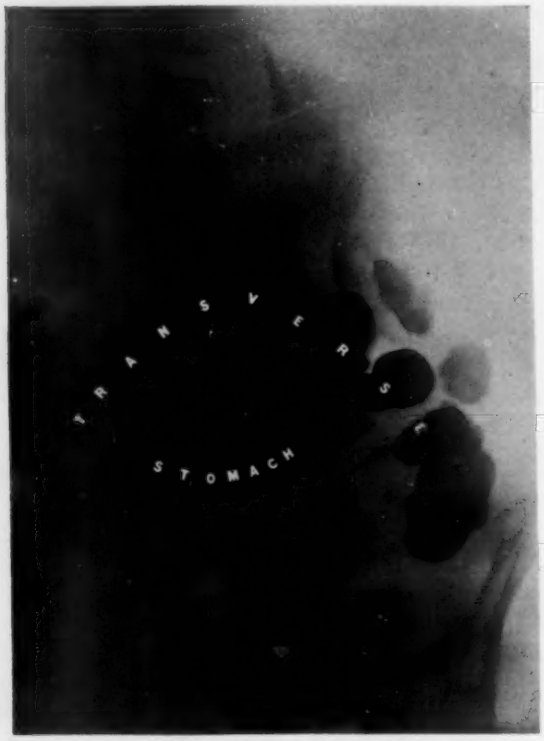

FIG. 3. A part of the greater curvature of the stomach is seen below the level of the transverse colon.

Male, aged forty (No. 7309). Cecum: on the linea terminalis (i.e., in 3d position). Ascending colon: average length, dextroconvex. Flexura coli dextra: at the level of the 4th lumbar vertebra; the two arms of the angle lay parallel for more than half of the length of the ascending colon; presence of adhesions inferred. Transverse colon: cranioconvex; peak of convexity about the level of the 3d lumbar vertebra. The lowest point of the greater curvature of the stomach: at the level of the 5th lumbar vertebra. Flexura coli sinistra: about the level of the 2d lumbar vertebra.

FIG. 4. Illustrates the skeletal level of the lowest point of the greater curvature of the stomach.

This point was: at the level of the 2d lumbar vertebra in 1 per cent (2 male, 1 female); at the level of the 3d lumbar vertebra in about 3 per cent (6 male, 2 female); at the level of the 4th lumbar vertebra in about 19 per cent (45 male, 11 female); at the level of the 5th lumbar vertebra in about 42 per cent (65 male, 60 female); below the level of the promontorium in 36 per cent (32 male, 76 female).

It is of interest to note that in the majority of the males (in about 73 per cent) the lowest point of the greater curvature of the stomach lay at the level of the fourth or fifth lumbar vertebra (in 45 cases, or 30 per cent, at L_4, and in 65 cases, or about 43 per cent, at L_5) and in only 32 cases or about 21 per cent of the 150 males did it reach lower than the level of the promon-

torium. In the females, on the other hand, the lowest point of the greater curvature of the stomach was found, in the majority of the cases (in about 91 per cent) at the level of the fifth lumbar vertebra (in 60 cases or 40 per cent) or below the level of the promontorium (in 76 cases or about 51 per cent). In males there were 8 cases in which the greater curvature of the stomach lay above the level of the fourth lumbar vertebra (6 at L_3, and 2 at L_2) and in females 14 cases in which it was above the level of the fifth lumbar vertebra (11 at L_4—compared with 45 in males, 2 at L_3, and 1 at L_2). The greater curvature of the stomach was thus found again, as an average, to reach lower in females by the height of the body of one vertebra, than in males (Fig. 4).

THE FLEXURA COLI SINISTRA

In 65 cases (24 male, 41 female) the last portion of the transverse colon and the first portion of the descending colon did not contain sufficient barium to determine the position of the splenic flexure (flexura coli sinistra). In 104 (51 male, 53 female) or about 44 per cent of the remaining 235 cases the splenic flexure was located at the level of the third lumbar vertebra (L_3); in 73 cases (46 male, 27 female), or about 32 per cent, it was *above*, and in 58 cases (29 male, 29 female), or about 25 per cent, it was *below*. In those found above the level of the third lumbar vertebra, 57 (32 male, 25 female) were at L_2, 11 (10 male, 1 female) at L_1, and 5 (4 male, 1 female) were at Th_{12}. In those found below the level of the third lumbar vertebra, 53 (28 male, 25 female) were at L_4, and 5 (1 male, 4 female) at L_5.

The presence of adhesions between the transverse and the descending colon was inferred in 85 cases (37 male, 48 female) or about 36 per cent of the 235 cases in which the splenic flexure was properly outlined.

THE COLON DESCENDENS AND THE COLON SIGMOIDEUM

The descending colon and the sigmoid are not considered here in detail because in almost half of the cases they were empty at the time of observation. In some instances, as mentioned before, the sigmoid may be seen above the transverse colon. This naturally occurs only when the transverse colon has a low position. Out of the 159 cases (92 male, 67 female) in which the sigmoid contained some barium, a part of the sigmoid was seen above the transverse colon in 10 cases (3 male, 7 female).

ANALYSIS OF DATA ACCORDING TO SEX

The *cecum* was found in the fossa iliaca in about 25 per cent of the males and in only about 9 per cent of the females. Except for the 2 per cent of the males in which it was situated about the level of the crista iliaca, the cecum was in a lower position than the fossa iliaca, i.e., on the linea terminalis in 50 per cent of the males and in about 47 per cent of the females, and in the pelvis minor in about 23 per cent of the males and in about 43 per cent of the females.

The *ascending colon* was of average length in about 59 per cent of the males and in 60 per cent of the females. It was longer in 20 per cent of the males and in about 29 per cent of the females, and it was shorter in about 21 per cent of the males and in about 11 per cent of the females.

The *flexura coli dextra* formed an approximately right angle in only about 9 per cent of the males and in 6 per cent of the females. In the others it was an acute angle and the first portion of the transverse colon lay parallel with the ascending colon in about 41 per cent of the males and in 30 per cent of the females for half of the length or less of the ascending colon, and in 22 per cent of the males and in about 35 per cent of the females for more than half of the length of the ascending colon. The presence of adhesions about the hepatic flexure was inferred in about 55 per cent of the males and in about 49 per cent of the females. The hepatic flexure was situated at the level of the fourth lumbar vertebra in about 53 per cent of the males and in about 57 per cent of the females. It was located above this level in 26 per cent of the males and in about 11 per cent of the females, and below the level of the fourth lumbar vertebra in

about 21 per cent of the males and in about 31 per cent of the females.

The *transverse colon* was caudoconvex in all but 3 (2 per cent) of the males and one of the females. Its course was regular in all but 12 per cent of the males and in only about 7 per cent of the females. In all but 3 of the males and 2 of the females the transverse colon was found at a lower level than the greater curvature of the stomach. The most dependent portion of the transverse colon was located above the level of the promontorium in about 35 per cent of the males and in only about 7 per cent of the females. It reached below the level of the promontorium in the rest, or in about 65 per cent of the males and in about 93 per cent of the females.

The lowest point of the *greater curvature of the stomach* reached lower than the level of the third lumbar vertebra in about 95 per cent of the males and in 98 per cent of the females. It was found at the level of the fourth lumbar vertebra in 30 per cent of the males and in only about 7 per cent of the females, at the level of the fifth lumbar vertebra in about 43 per cent of the males and in 40 per cent of the females, and below the level of the promontorium in about 21 per cent of the males and in about 51 per cent of the females.

As to the fusion of the layers of the greater omentum: *perfect fusion* (1) was inferred in 50 per cent of the males and in only about 21 per cent of the females; *non-fusion* (2) i.e., an absence of the so-called gastrocolic ligament in about 23 per cent of the males and in 48 per cent of the females; an *imperfect fusion* (3) in 20 per cent of the males and in about 25 per cent of the females, and an *irregular fusion* (4) was deduced in about 3 per cent of the males and in about 3 per cent of the females.

The *flexura coli sinistra* was properly outlined in 126 of the males and in 109 of the females. Of these it was situated at the level of the third lumbar vertebra in about 41 per cent of the males and in about 48 per cent of the females. It was located above this level in about 36 per cent of the males and in about 25 per cent of the females, and below the level of the third lumbar vertebra in about 23 per cent of the males and in about 27 per cent of the females. The presence of adhesions between the transverse and the descending colon was inferred in about 29 per cent of the males and in about 44 per cent of the females.

The *descending colon* and the *sigmoid* were empty at the time of observation in almost half of the cases. The sigmoid contained some barium in 92 males and in 67 females. Of these a part of the sigmoid was noted above the transverse colon in about 3 per cent of the males and in about 10 per cent of the females.

DISCUSSION

Roentgenoscopy and roentgenography furnish excellent means for the study of the shape, position, peritoneal and topographical relations of the colon in the living. Comparable data on any number of cases, however, can only be obtained if at least two of the main pitfalls of error are avoided. One of these is the omission of consideration of the influence of posture upon the shape, position and topographical relations of the abdominal organs; the other is the designation of the levels and distances by measures other than those furnished by the body itself.

In our series the first mentioned pitfall was avoided by taking all the final readings uniformly in the upright position of the subject, this being the only situation in which all the abdominal viscera naturally assume their lowest possible position. The second pitfall was avoided by expressing the levels and distances by means furnished by the individual's own skeleton. The fact that most of the available anatomical and roentgen-anatomical data are not entirely free from the one or the other or both of the objections just mentioned, is certainly at least in part responsible for our data being in many respects at variance with the current notions on skeletotopy and syntopy of the colon.

SUMMARY

This paper is the second report on studies carried on by the writers to secure roentgen-anatomical data on the colons of patients with pulmonary tuberculosis. By recording all the final readings uniformly in the

upright position of the subject and by expressing the levels and distances by means furnished by the individual's own skeleton, the writers believe they have avoided the usual pitfalls of error in collecting data of similar nature.

The *cecum* was found on the linea terminalis in 50 per cent of the males and in about 47 per cent of the females, and in the pelvis minor in about 23 per cent of the males and in about 43 per cent of the females. The *hepatic flexure* was an acute angle, and the first portion of the transverse colon lay parallel with the ascending colon for half of the length or less of the ascending colon in about 41 per cent of the males and in 30 per cent of the females, for more than half of the length of the ascending colon in 22 per cent of the males and in about 35 per cent of the females. The *transverse colon* was found in all but 3 males and 2 females at a lower level than the greater curvature of the stomach. The most dependent portion of the transverse colon reached below the level of the promontorium in about 65 per cent of the males and in about 93 per cent of the females. The lowest point of the *greater curvature of the stomach* reached lower than the level of the third lumbar vertebra in about 95 per cent of the males and in 98 per cent of the females. It was found below the level of the promontorium in about 21 per cent of the males and in about 51 per cent of the females.

Perfect fusion, non-fusion, imperfect fusion and irregular fusion of the layers of the greater omentum were judged by the relative position of the stomach and the transverse colon as seen during roentgenoscopic examination and found by palpation and roentgenograms. *A perfect fusion* (1) was inferred in 50 per cent of the males and in only about 21 per cent of the females; *non-fusion* (2) i.e., an absence of the so-called gastrocolic ligament in about 23 per cent of the males and in 48 per cent of the females; an *imperfect fusion* (3) in 20 per cent of the males and in about 25 per cent of the females; and an *irregular fusion* (4) was deduced in about 3 per cent of the males and in about 3 per cent of the females. Adhesions between the ascending and the transverse colon were inferred in about 55 per cent of the males and in about 49 per cent of the females, between the transverse and the descending colon in about 29 per cent of the males and in about 44 per cent of the females.

OSSIFICATIONS OF THE COSTAL CARTILAGES: THEIR RELATION TO HABITUS AND DISEASE

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TO the novice in roentgenology the early strand-like, beaded, or at times bizarre ossifications of the costal cartilages offer opportunities for confusion with pathological processes; to the novitiate they are readily recognizable, and offer cause for speculation as to their cause, and their relation, if any, to disease.

As early as 1859 Freund suggested that the early ossification of the first costal cartilage, by immobilizing the apex, was a cause of apical tuberculosis, and cited cases showing a greater incidence of ossification in the tuberculous. He also believed that early extensive ossification was a concomitant, and probable etiological factor in the development of emphysema.

A casual examination of a film or specimen shows that only a minute amount of lung lies above the first rib, which renders this theory unlikely; moreover, Wenckebach[1] after a study of numerous films, could discern no correlation between the narrow rigidity caused by ossification and the localization of the tuberculosis.

There is, however, the possibility that the disease influences the ossification, rather than vice versa. With this in mind Wernscheid[2] studied 651 cases and the corresponding films, with particular reference to hilum tuberculosis. He found that:

1. The youngest child showing ossification was aged nine.

2. In 6 of 73 children (8 per cent) there was ossification. All 6 of these showed hilum involvement; in 4 of the 6 ossification was of the first rib.

3. The ossification is a favorable character in tuberculosis.

4. There is a possible correlation between hilum tuberculosis and emphysema.

While rather convincing, Wernscheid's work can be criticized because it offers no comparison with the normal, but only between various types of tuberculosis.

Diametrically opposed to these findings are some of the French writers, as Bezançon, Jacquelin and Tribout[3] who say: "Ossification is rare in tuberculosis, as it was found but 9 times in 105 cases; all of these 9 were of the bronchial type, with hemoptysis, etc." They never found it under twenty-four years. They also state that "5 of the 9 cases were at least forty years of age; therefore the influence of age on the frequency of the lesion is very slight."

Ameuille perhaps comes near the truth when he suggests that it is a succession of natural events; of the growth of cartilage, and the lack of interstitial circulation; that the ossification is a simple reparative process from a necrosis of denutrition.

The most recent work is by Rist, Gally and Trocmé[4]. They have analyzed 500 roentgenograms of chests without regard to the presence or absence of pathology. They conclude that:

1. Ossification should begin to appear at the age of seventeen in males and nineteen in females.

2. There is an age when the first costal cartilage is ossified in all. This age is earlier in men (about thirty-five years) than in women (forty-five years).

They observe the following in regard to extensive ossification (i.e., more than the first costal cartilage): "In the first place, the very great rarity in the female sex at all ages, and secondly, their absence, in the male sex, up to about thirty years."

To determine whether tuberculosis actually bears a relation to ossification, and also to investigate the relationship of habitus and of syphilis, the following work was undertaken. Five hundred and forty-one cases with their roentgenograms were analyzed. The tuberculous group were successive cases, excluding those insufficiently worked up. The normal cases were ones which were carefully selected from about 2000 patients of whom roentgenograms had been made. All who had syphilis, nephritis, cardiac disease, emphysema,

metabolic disorders, in short, any chronic constitutional disease, were excluded. Most of the cases had been roentgenographed for the purpose of determining fractures, or pneumonia.

For purposes of study each case was grouped into one of the following classes:

I. Partial ossification of the first costal cartilage.

II. Complete ossification of one or both first costal cartilages.

III. Partial or complete ossification of the first costal cartilage plus partial ossification of the other cartilages.

IV. Complete or nearly complete ossification.

The following is an analysis of the cases:

TABLE I

NORMAL MALES—110 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	16	13	3	0	0	0
21–29	11	2	5	3	1	0
30–39	17	0	5	9	1	2
40–49	23	1	4	13	4	1
50–59	6	0	3	14	9	0
60–	21	0	2	10	8	1

TABLE II

NORMAL FEMALES*—104 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	8	4	4	0	0	0
21–29	13	5	3	5	0	0
30–39	18	4	7	6	1	0
40–49	15	1	3	10	1	0
50–59	17	2	1	11	4	0
60–	33	0	12	16	5	0

* Under "Normal Females" are included some cases of syphilis of so recent infection that there could be no effect on the cartilages.

TABLE III

TUBERCULOUS MALES—179 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	11	7	3	3	0	0
21–29	25	9	8	6	2	0
30–39	33	4	9	14	4	2
40–49	42	0	5	20	13	4
50–59	41	0	6	10	20	5
60–	25	2	7	6	7	3

NOTE: Those tuberculous males who also had syphilis are not included in the above but are analyzed in Table IV. (Tuberculous luetic females were not studied because of the few cases available.)

TABLE IV

TUBERCULOUS LUETIC MALES—41 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	0	0	0	0	0	0
21–29	6	5	1	0	0	0
30–39	7	0	2	5	0	0
40–49	11	1	1	4	3	2
50–59	12	0	1	5	3	3
60–	5	0	0	2	2	1

In Table IV and in Table V there are very few cases in the younger age groups, because all cases were discarded whose luetic history did not date back at least three or four years.

TABLE V

LUETIC MALES (NOT TUBERCULOUS)—25 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	0	0	0	0	0	0
21–29	1	0	0	1	0	0
30–39	5	0	0	4	1	0
40–49	8	0	1	6	1	0
50–59	8	0	0	2	5	1
60–	3	0	0	1	2	0

TABLE VI

TUBERCULOUS FEMALES—81 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	15	9	4	1	1	0
21–29	30	15	12	3	2	0
30–39	14	0	4	8	2	0
40–49	11	0	3	8	0	0
50–59	6	0	0	5	1	0
60–	5	0	3	1	1	0

There is no duplication of cases in the above analyses. Table VII, however, regroups the material of Tables III and IV. It includes only those cases in which the course of the tuberculosis was longer than two years at the time of examination. The purpose of this was two-fold: (1) because it was felt that any effect of the tuberculosis upon ossification would be accentuated in the long-standing cases, and (2) to investigate Wernscheid's tenet that early ossification was of favorable prognostic import (obviously if the latter's view is correct this group should show the greatest extent of ossification, since those with poor

prognosis have been in large part eliminated from it by death).

TABLE VII

MALES HAVING TUBERCULOSIS OF TWO OR MORE YEARS' DURATION—103 CASES

Ages	Cases	No Ossification	Stage I	Stage II	Stage III	Stage IV
15–20	0	0	0	0	0	0
21–29	11	2	3	5	1	0
30–39	18	3	3	11	1	0
40–49	29	0	3	20	4	2
50–59	31	0	3	8	16	4
60–	14	1	5	4	4	0

In Tables VIII and IX all of the preceding is condensed for comparison. Figures are given in percentages. In Table VIII are given figures for the ossification of the first costal cartilage only. This includes Stages I and II.

TABLE VIII

OSSIFICATION OF THE FIRST COSTAL CARTILAGE

Ages	15–20, Per Cent	21–29, Per Cent	30–39, Per Cent	40–49, Per Cent	50–59, Per Cent	60– , Per Cent
Normal males	6	82	100	96	100	100
Normal females	50	61	66	92	88	100
Tuberculous males	46	64	88	100	100	92
Tuberculous luetic males	..	16	100	91	100	100
Luetic males	..	100	100	100	100	100
Tuberculous females	40	50	100	100	100	100
Males, tuberculosis 2 years or more	..	82	79	100	100	92

In Table IX Stages III and IV are summarized:

TABLE IX

PARTIAL OR COMPLETE GENERAL OSSIFICATION

Ages	15–20, Per Cent	21–29, Per Cent	30–39, Per Cent	40–49, Per Cent	50–59, Per Cent	60– , Per Cent
Normal males	0	9	17	22	35	43
Normal females	0	0	5	6	23	14
Tuberculous males	0	8	18	41	61	40
Tuberculous luetic males	..	0	0	45	50	60
Luetic males	0	0	20	13	75	66
Tuberculous females	6	7	14	0	17	20
Males, tuberculous 2 years or more	0	9	6	21	32	28

A study of these tables shows that they agree closely with the findings of Rist, Gally and Trocmé.[4] Thus it is shown that ossification of the first costal cartilage has occurred in practically all individuals at about thirty years of age, the female lagging somewhat behind the male; the sexual difference is also pronounced as regards extensive ossification, which is seen to be more common in the male. The tuberculous groups show the same extents of ossification as the normals.

Of particular interest is the fact that those groups containing patients whose tuberculosis lasted two years or longer do not differ essentially either from the normal or from the general tuberculous groups. This seems to destroy Wernscheid's claim that ossification is of favorable prognostic import.

It would appear, however, that the syphilitic patients show a greater amount of ossification than the normal or the nonluetic tuberculous cases; this factor is more prominent in the upper age groups, as would be expected. A greater number of cases in these groups would have been more satisfying, of course.

In Table X the factor of habitus is considered. Nomal and luetic cases regardless of sex are included, but tuberculous cases are excluded because of the effect of changing the habitus which the disease exerts.

TABLE X

HABITUS—227 CASES

Habitus	No Ossification	I	II	III	IV
Hypersthenic	2(7%)	4(15%)	12(45%)	8(30%)	2(7%)
Sthenic	14(11%)	28(22%)	63(51%)	18(15%)	1(1%)
Hyposthenic and asthenic	14(18%)	18(23%)	30(38%)	14(18%)	2(3%)

It is thus seen that habitus bears no relation to ossification.

SUMMARY

The ossification in the costal cartilages in 541 cases was analyzed, and correlated with the incidence of tuberculosis, syphilis, and habitus. The findings of Rist, Gally and Trocmé that the ossification proceeds more rapidly in the male were corroborated. No relationship with tuberculosis, either as an etiological factor or as a result, could be discerned; this is contrary to the findings of certain German authors, who consider early ossification as a cause of tuberculosis, and also as a character of favorable prognostic import.

No relationship to habitus was discovered.

Extensive ossification appeared to be more frequent in syphilitic patients, particularly in the upper decades of life. However, the very wide range in the stages of ossification which can be discerned in any age group makes this sign of very limited value in the individual case.

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CRITERIA FOR THE DESIGN OF A STANDARD IONIZATION CHAMBER*

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DURING the last few years considerable progress has been made towards the eventual standardization of roentgen-ray measurements for practical purposes. At present it is almost generally agreed that of the many effects (physical, chemical, biological) which short wave radiation is capable of producing, ionization of gases is the most convenient for purposes of measurement. It is also generally accepted that air is a suitable ionizing medium. But there is no unanimity of opinion in regard to the actual construction of the measuring apparatus, nor is it likely that one particular design will be entirely satisfactory for all purposes. On the other hand, it is very desirable that an agreement be reached on some instrument to be used as a standard of comparison.

Many experimenters have worked on this problem and several instruments have been developed. Each embodies an ionization chamber and an electric device with which to measure ionization. The necessary requirements of such devices are well known and the choice of one or another depends chiefly on convenience of operation for the purpose at hand. If ordinary care is exercised the degree of ionization in a given chamber (ionization current) may be determined accurately irrespective of the electrical device employed. On the other hand, measurements of roentgen radiation by ionization depend to a large extent on the design of the chamber. Accordingly the cardinal part of a measuring instrument of the type considered here is the ionization chamber.

When roentgen-ray measurements are to be expressed in absolute units it is necessary to determine the ionization per unit volume. Therefore the volume of the air in which the ionization is measured by the electrical instrument must be known. Ionization chambers may be divided into two general groups: (1) Those in which the effective volume of ionized air is limited by the walls of the chamber, and (2) those in which the volume of the air in which ionization is measured is limited by some other means. The former are usually small chambers having a volume of the order of 1 c.c., while the latter are much larger. It is the opinion of most physicists engaged in this work that the large chamber is preferable as a standard. The work to be described in this paper was carried out with a large chamber.

DESIGN OF EXPERIMENTAL CHAMBER

In the past each experimenter has designed his ionization chamber according to his own ideas as to shape, size, arrangement of electrodes, etc. There is general

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agreement, however, in regard to a few important requirements: (1) Adequate protection from stray radiation must be provided. (2) The dimensions of the chamber must be large enough to make sure that no part of the largest beam

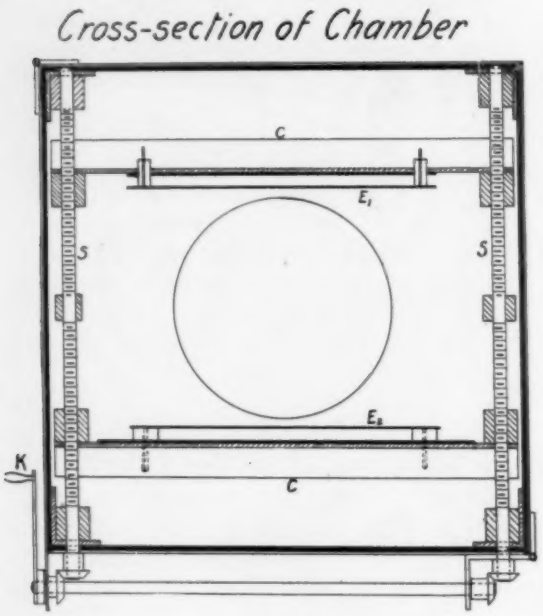
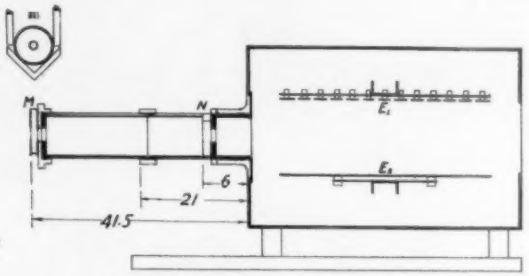


FIG. 1.

which enters it touches any part of the chamber. (3) The distance between electrodes must be sufficient to insure (almost) complete absorption of the photoelectrons liberated in the air. (4) The electric field between electrodes must meet certain requirements to make possible the measurement of ionization in a well-defined volume of air. Guard electrodes are usually provided for this purpose. It has been assumed that the cross section of the beam of rays which enters the chamber is determined by the area of a limiting diaphragm placed in front of the chamber. Several experimenters have mentioned the use of additional diaphragms to block out stray radiation and radiation from the stem of the tube target, but there is no definite arrangement which is generally accepted.

Our ionization chamber was designed to conform with these requirements and at the same time permit variations of the different factors involved within wide limits and by simple manipulations. A cross section of the chamber is shown in Figure 1 and a longitudinal section in Figure 2. The outside case is 36 × 36 × 53 cm. and is made of brass. It is lined with lead 3.2 mm. thick as protection from scattered radiation. (The



Longitudinal Section of Ionization Chamber

FIG. 2.

roentgen tube itself is surrounded by 4.8 mm. of lead.) The electrodes E_1, E_2 are parallel plates of aluminum 22 × 42 cm., and are supported by two other aluminum plates from which they are electrically insulated by amber blocks. The plates are held in position by two brass channels, C. These are attached to brass nuts which run on two steel screws, S, with right and left threads. The two screws are geared to a crank, K, so that they can be turned synchronously. By this means it is possible to adjust very quickly the distance between the electrodes to any desired value between 4.6 and 24 cm.

Referring to Figure 2 it will be seen that electrode E_1 is made up of eleven parallel strips 3.8 × 22 cm. arranged in the same plane so that adjacent ones are spaced 0.25 mm. apart. Each strip is supported by separate amber insulators and can be used as an electrode independently of the others. Means are also provided for connecting any number of strips to form an electrode of variable size or to be earthed. In this way the effective length of electrode E_1 may be varied from 3.8 to 42 cm. in equal steps.

Figure 2 shows also the construction of the ends of the chamber. One end has a circular opening 14 cm. in diameter which is much larger than the diameter of the emergent beam of radiation at this point. The other end is provided with a brass tube 8.9 cm. in diameter whose length can

be varied in three steps as indicated: 6, 21, and 41.5 cm. The tube has a lead lining 3.2 mm. thick, and a lead disc at the end 10 mm. thick with a central hole 25.4 mm. in diameter. A brass cap which closes the end of the hole in front of the lead disc is provided (at M) with a V-support (Fig. 2(*a*)), for diaphragms of different sizes. These are made up of brass rings 3.8 cm. in diameter and 1.27 cm. deep in which a type metal disc has been cast (Fig. 2(*a*)). The V-support and the brass rings are carefully machined so that diaphragms may be interchanged without altering the direction of the radiation beam entering the chamber. A second V-support is placed at N so that, through a slot in the brass tube, diaphragms of different sizes may be inserted at this point. A third V-support is attached to the roentgen tube holder at L (see Fig. 3). In this manner it is possible to have diaphragm combinations differing not only in aperture but also in position relative to the electrodes and the roentgen tube, independently.

EXPERIMENTAL SET-UP

Figure 3 shows the arrangement of the ionization chamber and the roentgen tube. The latter is enclosed in an aluminum cylinder 62 cm. in diameter, lined with lead 4.8 mm. thick. A large opening, which permits replacement and cleaning of the roentgen tube, is covered with adjustable overlapping lead shutters, each 3.2 mm. thick. At the point of emergence of the beam of rays is mounted the V-support, L, already mentioned. Its position is adjustable in two directions at right angles to facilitate alignment. The cylindrical tube holder rests on wooden supports which are attached to the end of a long table, while the ionization chamber is mounted on an adjustable platform which runs on tracks screwed to the table. It is thus possible to vary the distance between the roentgen tube and the center of the chamber from 86 to 144 cm. Alignment of the diaphragms can be brought about by manipulating the leveling screws of the chamber, shifting the diaphragm, L, and the roentgen tube in the holder.

The roentgen tube employed in the experiments is an ordinary Coolidge air-cooled deep therapy tube. The "focal spot" of the solid tungsten target in these tubes is intended to be 12 mm. in diameter. (This was confirmed by pinhole pictures.)

The machine which feeds the tube is a "constant voltage" apparatus manufac-

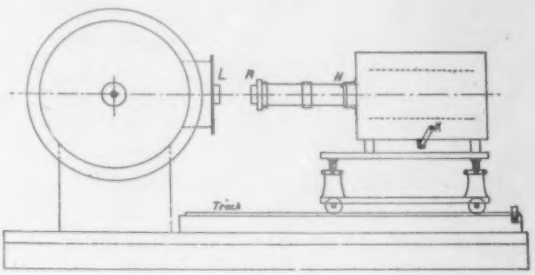


FIG. 3.

tured by the Wappler Electric Company. It consists of three closed core transformers, operating at 60 cycles, four hot cathode rectifiers and condensers. Full wave rectification is employed and the condensers are of sufficient capacity to give a substantially constant voltage at 4 to 6 ma., according to the manufacturers. The machine is capable of operating at 200 kv., but all our experiments were made at lower voltages since it is difficult to find roentgen tubes which work well at 200 kv. under these conditions. At the lower voltages close duplication of readings can be obtained during the course of an experiment and also from day to day, unless the primary voltage fluctuations are unusually large (over 3 or 4 per cent).

MEASURING APPARATUS

For the measurement of ionization currents two different methods were adopted: (1) direct reading, and (2) compensation or null. In either case, the master electrode of the chamber is essentially at earth potential. A high sensitivity Leeds and Northrup galvanometer of the D'Arsomal type is employed for the direct reading method. Its current sensitivity is 10^{-11} ampere per millimeter deflection with the scale at one meter. In our case the scale is at a distance of 150 cm. and therefore the sensitivity is 7×10^{-12} ampere or about 0.02 e.s.u. per millimeter. This instrument does not give large deflections with small electrodes and

narrow beams or low intensities of radiation. Furthermore, for accurate work with widely different readings its range is not sufficiently large. Accordingly the second method was employed for all the experiments described in this paper. The reason

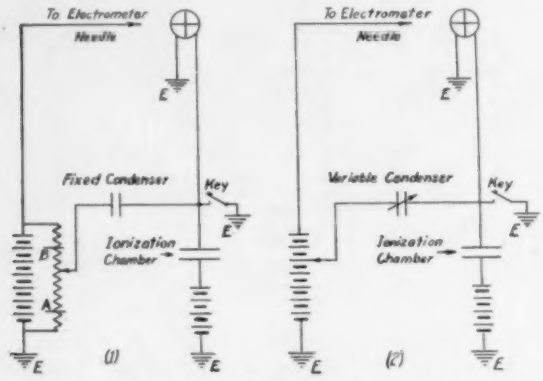


FIG. 4.

for using the galvanometer method was to obtain independent measurements of the same ionization current in electrostatic units by two different methods.

The advantages of compensation or null methods of measurement are well known and need not be mentioned here. For the benefit of those who are not familiar with physical measurements we may say, however, that the general idea is to neutralize the ionization current by another current which can be controlled and measured with accuracy and ease directly or indirectly. A sensitive instrument in the nature of a detector is required to determine when exact neutralization has been obtained. In our case this is a quadrant electrometer of the Curie type. The compensating current is of the same magnitude as the ionization current and therefore its value is determined indirectly. The principle is as follows: The relation between voltage, capacity and quantity of electricity in a charged condenser is $Q = CV$ where the symbols are self-explanatory. Differentiating with respect to time we get

$$\frac{dQ}{dt} = V\frac{dC}{dt} + C\frac{dV}{dt}$$

if both the voltage and capacity vary with the time. Or, for a constant capacity

$$\frac{dQ}{dt} = C\frac{dV}{dt}$$

and for a constant voltage

$$\frac{dQ}{dt} = V\frac{dC}{dt}.$$

We have here two simple methods of producing a small electric current: (1) by varying the voltage applied to the condenser keeping the capacity constant, or (2) by varying the capacity keeping the voltage constant. To obtain a constant current during a certain interval of time it is only necessary to vary the voltage or the capacity at a uniform rate. Either procedure is very well suited for the compensation of ionization currents.

Before discussing the determination of the magnitude of the compensating current (or the ionization current since the two are equal), it may be well to examine the wiring diagrams for the two methods, as used in practice. They are given in Figure 4. In (1) we have a condenser of fixed capacity and slide wire potentiometer by means of which the voltage on the condenser is varied. When the slide is moved at a constant rate between the points A and B a constant current flows towards the electrometer. For a given condenser the magnitude of the current depends on the voltage drop between A and B and on the speed at which the slide is moved. In (2) we have a variable condenser to one set of plates of which is applied a given voltage. By varying the capacity of this condenser at a constant rate between two given values, a constant current may be sent to the electrometer. For any applied voltage the magnitude of the current depends on the *change in capacity* and on the rate at which the change is made. It will be seen that in both cases the compensating current is of limited duration.

When the voltage on a condenser of capacity C changes from V_1 to V_2 the charge on the condenser changes from Q_1 to Q_2. Accordingly a quantity of electricity $Q_2 - Q_1 = Q$ must flow to or from the condenser. If the change takes place in time T then the average current flowing during the interval is $\frac{Q}{T} = C\frac{V_2 - V_1}{T}$. Hence by measuring the capacity of the condenser, the difference in voltage between A and B and the time during which the slide moves from

A to B, one can determine the magnitude of the average current during the interval. Similarly in case (2) where the capacity is changed continuously from C_1 to C_2 while the voltage remains constant at V, the average current $= \frac{Q}{T} = V\frac{C_2 - C_1}{T}$. Its value can be determined by measuring the voltage applied to the condenser, the total *change* in capacity of the variable condenser and the time interval.

The actual procedure in making ionization measurements with either method is as follows: The key which earths simultaneously one electrode of the ionization chamber, one set of plates of the condenser and one set of quadrants of the electrometer is raised. The electrometer needle will then begin to move. When this shows a certain deflection (say 1 cm.) the stopwatch is started and at the same time the rheostat slide is moved (or the variable condenser knob is turned) in such a way as to bring the electrometer needle back to zero and keep it at zero. Under these conditions the ionization current is being compensated by the induced current and the two must be equal during the time that the electrometer shows no deflection. After the full change in voltage (or capacity) has been made, the compensating current ceases and the electrometer needle will again move. When it shows the same deflection previously chosen (1 cm.) the stopwatch is stopped and the system is again connected to earth by lowering the key. With a little practice it is a simple matter to maintain the electrometer at zero deflection, or practically so, throughout the interval. In any case, if the insulation of the system is good, small oscillations about the zero point have no effect on the readings. It is hardly necessary to add that the whole electrical system must be very carefully shielded from electrostatic disturbances. The condenser should have good insulation and there should be guard rings between the two sets of plates. Also, the condenser should be protected from ionizing radiations.

These methods have been described somewhat in detail because they are admirably suited for work of this type. The variable condenser method is not new and probably the variable voltage method is also old since the principle is very simple. In addition to the advantages of null methods they possess very wide reading ranges which can be varied at will in a number of ways. The insulation need not be extremely high (as in the case of electroscopes) because the main system is always practically at earth potential. The cable connecting the ionization chamber to the electrometer (through the earthing key) may be quite long and the two pieces of apparatus may be set up in separate rooms. For standardization work the different magnitudes needed for the determination of the current can be measured without serious difficulties. Also the master electrode of the chamber is kept at substantially the same potential as the guard plates.

In most of our work, which required continuous operation for several hours at a time, the variable condenser method was used because in this case the battery is not shunted by a potentiometer and the voltage remains constant. The condenser was originally designed for this purpose by Dr. Harry Clark.[1] It is of the rotating type with a special conical bearing. It has four fixed and three movable plates with earthed guard rings between the two sets. Two of the four fixed plates may be connected to earth independently of the other two to provide a smaller capacity range. In operation the fixed plates are connected to the electrometer and the movable plates to the source of potential. Additional movable plates are provided so that the capacity of the *electrometer system* is essentially the same before and after rotation of the plates.

Since we are interested only in the *change* in the condenser capacity when the rotor is turned from one stop to the other, this was measured in the most direct way and at the same time the way in which it is used for the ionization measurements. That is, one set of plates was kept at a given voltage and the other set was connected to a high sensitivity ballistic galvanometer of very long period. By turning the rotor quickly from one stop to the other a certain

[1] *Physical Rev.*, 1915, vi, 43.

galvanometer "throw" was produced. This gave a measure of the quantity of electricity discharged through the galvanometer. Knowing the voltage applied to the condenser, the *change in capacity* was then determined. The ballistic galvanometer was calibrated by means of a standard condenser whose capacity was known accurately. The change in capacity for the condenser which was used for most of the experiments reported here, is: 108.8 micromicrofarads with four plates; 24.4 micromicrofarads with two plates.* A large variable condenser is available in order to bridge the gap between measurements with the above condenser and measurements which can be made with the high sensitivity galvanometer. The change in capacity with this condenser is 1000 micromicrofarads.

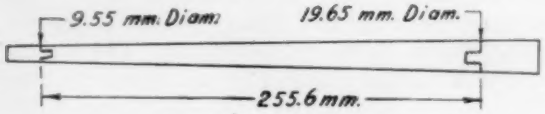


FIG. 5.

DIAPHRAGMS

As already mentioned the diaphragms used to define the beam of radiation are made of type metal, which is better than lead for this purpose. Brass rings are provided to protect the periphery since this alloy, while harder than lead, can be dented rather easily. (For some of the experiments it was very important to have diaphragms which could be changed without upsetting the alignment.) The brass rings are 3.8 cm. in diameter and the type metal is 1.27 cm. thick, which is more than sufficient to stop completely the hardest rays used in the experiments.

All of the diaphragms have circular apertures with a slight taper from one side to the other. The taper is a little greater than the divergence of the radiation beam (assuming a point source) for most of the distances from the target at which the diaphragms were placed.

Two sets were made. The diaphragms in one set were intended primarily for use directly in front of the ionization chamber to give beams of different cross section areas. They were turned in a precision lathe and were measured by means of a special tapered mandril. Diaphragms of the second set were intended for intermediary positions between the roentgen tube and the diaphragm at the entrance to the chamber. They were made by using standard reamers of different sizes. In all cases great care was exercised to make sure that the holes in the type metal discs were concentric with the brass rings, and that the edges of the apertures were sharp.

The construction of the special tapered mandril is shown in Figure 5. It was made of tool steel in three sections, A, B, C, screwed together rigidly. The taper was turned between centers for the mandril as a whole. Then the steel was case hardened and ground. By removing the section, C, it is possible to measure the diameter of the large end of the middle section, B, by means of micrometer calipers. It is 19.65 mm. The diameter of the smaller end of B was determined by removing A and measuring the large end of A, which corresponds to the small end of B. It is 9.55 mm. The distance between the two ends is 255.6 mm. and therefore the taper is 0.03951 mm. per millimeter. The diaphragms of the first set were made with this taper and were then fitted to the mandril. By measuring the distance of each from either end of section B, the diameters could be calculated. These diaphragms were designated by letters from A to F. The taper of the diaphragms of the second set is 0.0208 mm. per millimeter. The diameters were determined by using standard mandrils of the same taper and measuring with micrometer calipers the diameter of the mandril at the point where the smaller side of the aperture touched the conical surface. These diaphragms were numbered from 1 to 19. The diameters and cross section areas for all the diaphragms are given in Table 1. The figures refer to the smaller side of the tapered hole in each case.

PRELIMINARY TESTS

Experiments were made to determine the characteristics of the apparatus. Electrical insulation gave us no particular trouble, but electrostatic shielding required

*The capacity measurements were made in the Physical Laboratories of Columbia University by Dr. Carrelmeyer.

TABLE 1

No.	Diameter, Mm.	Area, Mm.^{2}
A	9.70	73.8
B	11.51	104.0
C	13.34	140.0
D	15.14	180.0
E	17.00	227.0
F	18.84	278.0
G	22.2*	388.0
1	2.68	5.65
2	3.08	7.4
3	3.46	9.4
4	3.73	10.9
5	4.15	13.5
6	4.51	15.9
7	4.96	19.3
8	5.34	22.4
9	5.75	25.9
10	6.10	29.2
11	6.41	32.2
12	6.84	36.7
13	7.24	41.2
14	7.68	46.3
15	8.10	51.5
16	8.45	56.0
17	8.86	61.5
18	9.25	67.1
19	9.66	73.3

* Measured directly with a millimeter scale.

various modifications before it could be considered complete. The precision of the measuring apparatus and the method of taking readings were determined by using radium as a source of radiation, in which case the ionization was constant. It was found that readings could be duplicated within ± 1 per cent. The precision of consecutive readings taken with roentgen rays as the ionizing agency was also ± 1 per cent when the primary voltage and milliamperage were kept constant by manual adjustments. At first thought this is rather surprising. The explanation, however, may be found in the fact that the voltage applied to the ionization chamber was produced by a valve tube rectifier with a condenser. It was not, therefore, as constant as in the case where batteries are used for this purpose. When the voltage is higher than required for saturation, reasonable variations in its value do not affect the magnitude of the ionization current, but the current measured is influenced by induced charges. Accordingly the error of ± 1 per cent found in readings taken with a constant ionization, was largely due to this cause rather than to variations inherent in the method of measurement *per se*. The duplication within ± 1 per cent of successive readings taken in the course of the experiments with roentgen rays is as good as can be expected in work of this sort with a commercial roentgen-ray machine. On some days unusual line voltage variations occurred which made it impossible to duplicate readings with the above precision. In such cases no important experiments were made even though readings could be duplicated within ± 2 per cent.

Tests were made to determine whether true proportionality exists between ionization currents and readings taken with the variable condenser method. The tests were made with radium tubes of different values and also by taking the eleven sections of the electrode, E_1, separately and together. Strict proportionality was found to exist for widely different readings. Readings were also taken of the same ionization current (using radium) with different voltages on the variable condenser and a satisfactory agreement was found.

As already mentioned, a valve tube rectifier was used to provide the required voltage for the ionization chamber. The apparatus consists of a step-up transformer with eight taps in the secondary varying by approximately 500 volts. A single kenetron is used to rectify the current and a condenser to smooth out the oscillations. Since the current drawn from this system is extremely small the voltage remains practically at its peak value continuously. Variations of the peak voltage do occur, however, whenever the line voltage changes.* The influence of such variations was found to be small (as already discussed) and we therefore felt justified in not using batteries, which would be rather expensive for the high voltage required. All the experiments were carried out with a difference of potential between the electrodes of the

* Alternating current at 60 cycles and 240 volts is supplied to the roentgen laboratory from the city mains through a step-down transformer of much larger capacity than the combined rated power of all the roentgen machines in the building. The wiring between each machine and the main transformer is also of much larger current carrying capacity than necessary and therefore the voltage at each machine is practically uninfluenced by the operation of other machines. Line voltage fluctuations in this part of the city (residential section) are usually small, ± 1 per cent.

chamber, more than sufficient to give saturation current, with the various settings employed. This point was determined experimentally by increasing the voltage in steps of 500 volts.

EXPERIMENTS

1. *Distribution of Electrostatic Field between Electrodes of Ionization Chamber.* In the experimental chamber already described the electrodes consist of two parallel plates 22 × 42 cm. The upper plate is made up of eleven equal strips 3.8 cm. wide, the air gap between adjacent ones being 0.25 mm. The object of these experiments was to get an idea of the field distribution between the electrodes with different spacings. The procedure was to connect each strip separately and successively to the electrometer, earthing all the remaining strips and then measuring the ionization current for each produced by the same beam of roentgen rays. This was done with the electrodes 4.6, 6, 7.5, 10, 12, 15 and 20 cm. apart. In all cases the largest cross section of the (conical) roentgen beam between the electrodes was less than 20 mm. in diameter. Two diaphragms were used and no part of the beam touched the electrodes even with the shortest spacing of 4.6 cm. Roentgen rays produced at a voltage of 110 kv. (approximately) and filtered by 0.1 mm. of copper and 2.15 mm. of aluminum were used in order that the absorption by air from one end of the chamber to the other might be negligible. The voltage between the electrodes was always 3500 volts, which had been found to be sufficient to produce saturation for the greatest spacing of 20 cm. The experimental results for the 10 cm. spacing between electrodes, obtained on two different occasions, are given in Table II. The ionization values are relative to that of the middle strip (No. 6) as 100 per cent. The two sets of entirely independent readings show within what limits agreement may be expected in our experiments and are given here for this purpose. The average values show that for a spacing of 10 cm. between electrodes the field may be considered longitudinally* uniform only within the three strips at the center (5, 6 and 7).

* In cross section the field is not uniform, but within certain limits this is immaterial for our purposes.

TABLE II

Strip No.	Relative Ionization		
	1st Exp.	2d Exp.	Average
1	110.3	112.0	111.2
2	92.3	92.3	92.3
3	97.1	97.1	97.1
4	98.8	99.5	99.2
5	100.4	99.1	99.8
6	100	100	100
7	100.4	99.8	100.2
8	99.1	99.8	99.5
9	97.3	97.2	97.3
10	91.5	91.0	91.3
11	93.7	93.7	93.7

For strips 4 and 8 the variation is within the experimental error, but since in both sets the readings are lower than 100 per cent, it is safe to conclude that the field is not quite uniform under these strips. It should be noted in passing that the two end strips do not give the same readings. This is due to the inequality in the windows at the two ends of the chamber (see Fig. 2 and also Fig. 7). Strip No. 1 is at the emergence end while strip No. 11 is at the incidence end of the chamber.

The results of experiments similar to the ones just described but for different distances between the electrodes are shown graphically in Figure 6. It will be seen that the uniform portion of the field decreases rapidly with increasing distance between the electrodes—as one would expect. In general the two end strips give a larger reading than the center strip, indicating a "bulging out" of the lines of force, thus increasing the volume of irradiated air from which ions are drawn. The difference in the readings of the end plates and lack of symmetry are due to the difference in the windows at the two ends of the chamber To visualize the field distribution we have constructed roughly the diagrams of Figure 7 for the 10 and 20 cm. spacings.

Estimating from the curves of Figure 6 the portion of the electrode under which the field may be considered to be longitudinally uniform for each spacing, we may derive the relation shown graphically in Figure 8. The ordinates represent the

fraction of the total length of the electrode under which the field may be considered to be uniform. The abscissae represent the distance between electrodes in percentage of the *length* of the electrodes. In other words, the variables are expressed in

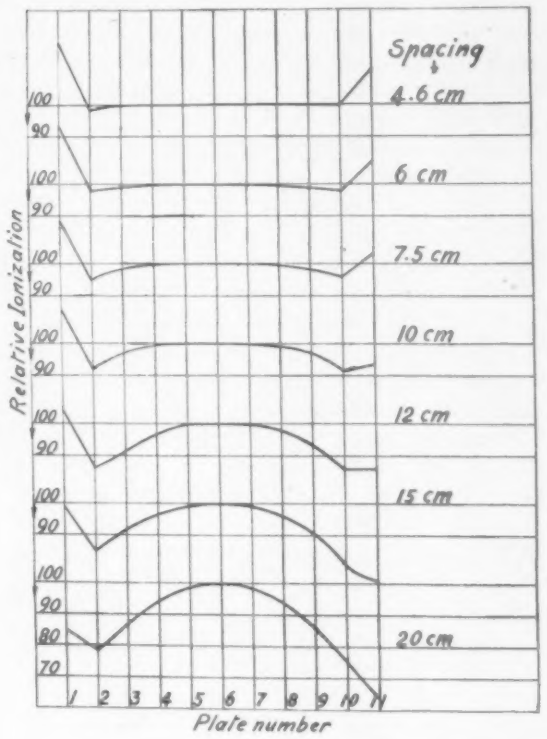
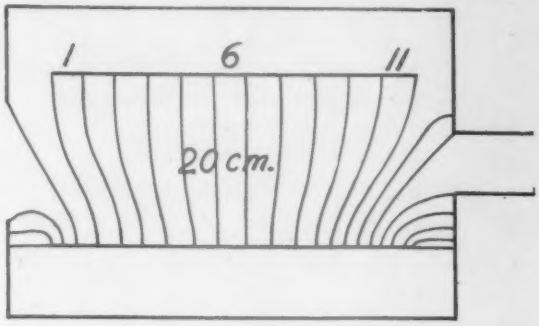


Fig. 6.

terms of the total length of the electrodes.* By means of this curve it is possible to determine the portion of the electrodes between which the field may be considered uniform for our ionization chamber and any other of different size but of the same general proportions. In designing a new chamber this information will give an idea of the size of the guard plates required for a given size of "master" electrode and any spacing between electrodes, within the limits of the curve. For instance, if the (parallel) plates of an ionization chamber are 10 × 20 cm., for a spacing of 5 cm. the field may be considered uniform within a central strip 4.8 cm. wide. Strictly speaking the curve of Figure 8 applies only to our chamber. But we believe that it may be used as a first approximation for other chambers which are built on the same general plan.

Referring again to the curves of Figure 6, we see that for the 15 and 20 cm. spacings it is doubtful whether the field is uniform even within the middle strip. To



Approximate Distribution of Field

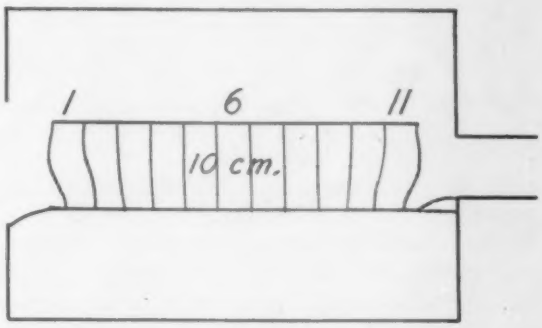


Fig. 7.

test this point a series of readings were taken in the following manner: The middle strip alone was connected to the electrometer (the others being earthed) and with the same roentgen-ray beam and the same voltage applied to the plates, consecutive readings were taken with the plates 6, 7.5, 10, 12, 15 and 20 cm. apart. The results are given in Table III.

Table III

Spacing in cm.	Electrometer Time in Sec.
6.0	53.4
7.5	53.3
10.0	52.8
12.0	53.2
15.0	52.8
20.0	55.1

*They could also be expressed in terms of the spacing which might be more convenient for some purposes.

It will be seen that all the readings except the last are alike within the experimental error. Therefore for spacings up to 15 cm. the field within the middle strip of the electrode may be considered uniform. The reading for the 20 cm. spacing is appreciably longer, showing that the ionization current was smaller. This could be due to: (1) insufficient voltage drop between the electrodes, or (2) non-uniformity of field. Since the voltage was known to be more than sufficient to produce saturation, the decrease in the current in this case indicates that the field was not uniform (see Fig. 7).

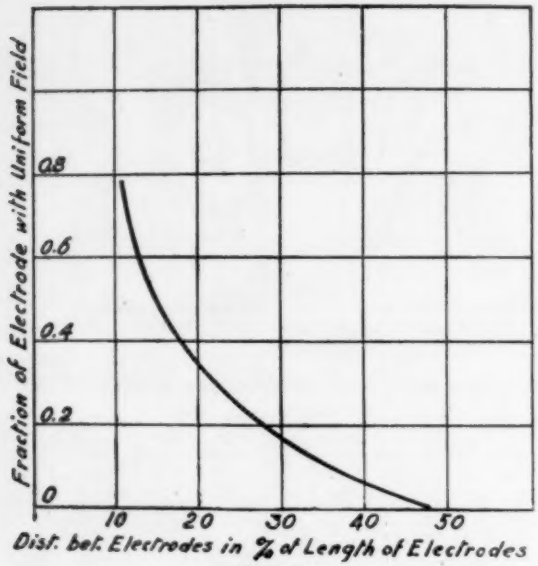


FIG. 8.

In order to have a uniform field over a reasonable distance at the center of the electrodes when the spacing is 20 cm., the electrodes should be considerably longer. It is possible, however, to accomplish the same result without altering the plates and the external dimensions of the chamber. Perhaps the simplest way to do this is to introduce thin rods across the ends of the chamber, parallel to the plates and charged to voltages corresponding to a uniform drop of potential from one electrode to the other. For instance, if four rods are used, they would be spaced 4 cm. apart so that each end one would also be 4 cm. from the plane of the electrode on that particular side. The one near the (earthed) guard plate would be kept at a potential of 800 volts, the second at 1600, the third at 2400 and the fourth at 3200; when the two electrodes are at 0 and 4000 volts, respectively. Readings taken under these conditions are shown in Table IV in which are also included for comparison the results of a similar determination without the charged rods. It will be noted that the addition of the charged rods produces a uniform field (within less than 1 per cent) under the five central strips of the electrode. The field is badly distorted near the ends of the electrodes. A better distribution throughout could probably be obtained by a rearrangement of the rods and the voltages applied to them. We feel, however, that in any practical case it is preferable to make the guard plates sufficiently long and thus avoid complications. Accordingly the investigation was not carried further.

TABLE IV

Strip No.	Relative Ionization	
	With Charged Rods	Without Charged Rods
1	33.3	83.9
2	137.0	78.7
3	102.0	86.2
4	99.7	94.3
5	99.4	98.5
6	100.0	100.0
7	99.4	98.0
8	100.0	94.1
9	103.6	86.6
10	138.0	74.8

2. *Collimation of Roentgen-Ray Beam.* In measuring the "intensity" of a beam of roentgen rays by means of so-called standard ionization chambers, the general procedure is to consider the effective volume of air irradiated as that of a cylinder* with a base equal to the aperture of the limiting diaphragm in front of the chamber, and a height equal to the width or depth of the master electrode plus the width of one of the two equal air gaps between the electrode and the guard plates. The measured "intensity" is then said to be for the point in the beam at which the aperture of the diaphragm is located. There is, however, no general

* When the diaphragm has a circular aperture.

agreement as to the use of additional diaphragms and their position with respect to the roentgen-ray tube and the main diaphragm. Certain recommendations have been made by individual workers in this field but, in our opinion at least, they have not been very definite. In view of the acknowledged desirability of setting up international standards for roentgen-ray measurements, it was thought worth while to make a fairly complete study of the influence of diaphragms on measurements with a chamber of the type described above.

The experimental procedure was as follows: All controllable factors were kept constant throughout the course of the experiments, with the exception of the particular factor under investigation. The roentgen machine was operated at a primary voltage of 105 volts* and a tube current of 4 ma. A filter of 1 mm. of aluminum was placed at the opening of the roentgen-ray tube holder (39 cm. from the target) where the overlapping adjustable lead shutters are located. The electrodes of the ionization chamber were placed 10 cm. apart and a voltage of 3500 was applied across them. Only the three center strips of the composite electrode were connected to the electrometer, while the others, serving as guard plates, were earthed.

In the first set of experiments two diaphragms were used to collimate the beam of radiation. One was placed at the opening of the roentgen-ray tube holder (position L, Fig. 3) directly in front of the filter. The other was placed within the long lead-lined tube of the chamber at N. The end of this tube in these experiments was open. The relative positions of roentgen-ray tube, diaphragms and ionization chamber are shown at the top of Figure 9. Good alignment was obtained by visual observation and was controlled by exposing films to the radiation reaching the far end of the chamber. In what follows we shall refer to the diaphragm in position L (43 cm. from the target) as the "near diaphragm," and to the one in position N (108 cm. from the target) as the "far diaphragm."†

The actual experimental procedure was as follows: Using one of the lettered diaphragms (A, B, C, etc.) as the far diaphragm, readings were taken with each of the diaphragms 1 to 19 and the remaining lettered ones as the near diaphragm. Several readings were taken in each case

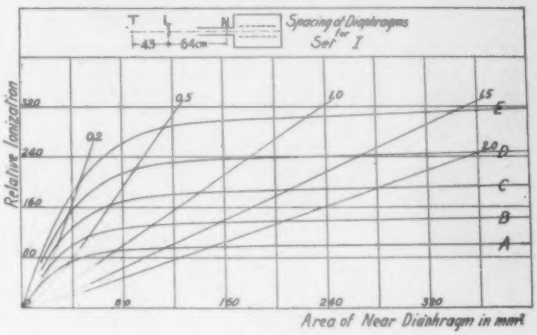


Fig. 9.

and, at the end of each series, check readings were taken with the first near diaphragm used in the series. Very good agreement was always found showing that no gradual changes took place during the time required to complete the series. In this way we determined the variation of the ionization when the aperture of the far diaphragm was kept constant and the size of the near diaphragm was varied within wide limits. This was done for several different apertures of the far diaphragm.

Since, of course, the work extended over a considerable period, it was desirable to cross check the whole group of experiments. For this purpose a second set of determinations was made in each of which the near diaphragm was kept constant and the far diaphragm was varied. The near diaphragms selected for this work were Nos. 12, 19, C and F taken in the following order for the purpose of further cross checking: Near diaphragm No. 12, far diaphragms A to E then A again; near No. 19, far A to E then A; near No. 12, far A; near C, far A to E then A; near No. 19, far A; near F, far A to E then A; near C, far A; finally Nos. 12, 19, C and F as near diaphragms with A as far diaphragm.

The data thus obtained are given in graphic form in Figure 9. With the exception of three or four, the experi-

* This corresponds to approximately 100 kv. on the tube.

† Accordingly the distance between the two diaphragms was 65 cm. Note that by an oversight 64 cm. is shown in Figure 9.

mental points for the whole series lie almost exactly on smooth curves* (originally plotted to a large scale). The ordinates in the figure represent the ionization produced in the chamber, under the conditions previously stated, with different

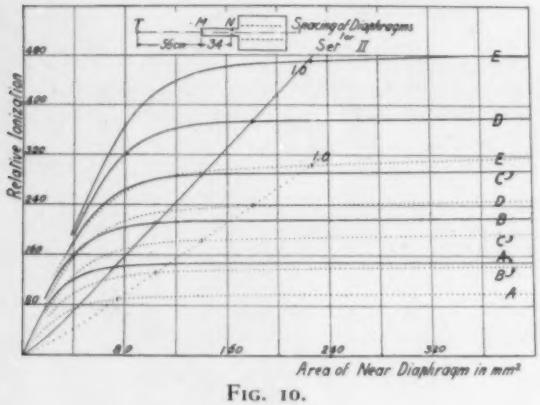


FIG. 10.

diaphragm combinations. They are expressed in arbitrary units relative to 100 for the ionization produced when G was used as the near diaphragm and A as the far one.

Before discussing the curves of Figure 9 we may recall that in all these experiments the near diaphragm was at a distance of 43 cm. from the target and the far diaphragm at 108 cm. Assuming a point source of radiation we can calculate the aperture of the near diaphragm which would subtend the same solid angle as the far diaphragm. It is found that the areas of the apertures should be in the ratio of 1 to 6.3 to fulfill this condition. Or the area of the near diaphragm should be 0.158 of the area of the far diaphragm. For the largest far diaphragm (E) of the curves in Figure 9 the "geometrical" aperture of the near diaphragm would be 36 mm.^{2}; while for smaller ones it would be correspondingly smaller. Glancing at the curves we find that the ionization increases rapidly with the size of the near diaphragm, considerably beyond the (calculated) geometrical aperture. For instance, in the case of far diaphragm E (227 mm.^{2}), the ionization for a near diaphragm of 36 mm.^{2} is 169, whereas for a near diaphragm of double the area it is 251. The ionization reading keeps on increasing with the area of the near diaphragm even beyond the point where both diaphragms are of the same size.

The five curves in Figure 9 all have the same general shape, but they cannot be made to coincide by suitable changes in scale. However, an interesting relation exists among them. If on each curve we mark the point at which the area of the near diaphragm is equal to that of the corresponding far diaphragm, we find that all these points lie almost exactly on a straight line. In the figure this line is marked "1.0" to indicate that the areas of corresponding near and far diaphragms are in the ratio of 1 to 1. Similarly if the areas are in any given ratio, corresponding points on the curves lie on a straight line. Several are shown in the figure.

This interesting property of the family of curves would lead to a useful generalization were it not for one difficulty—the *straight* lines do not pass through the origin. In fact they have no one point in common, whether this be the origin or otherwise. It is obvious, however, that the lines must pass through the origin and therefore they must curve in some way when small diaphragms are used. This is indicated in the figure by the dotted lines.

In order to determine how the relation between the apertures of the diaphragms and the ionization readings is influenced by the position of the two diaphragms and the ionization chamber with respect to the roentgen-ray tube, a second series of experiments was carried out. The experimental set-up is shown at the top of Figure 10 from which it will be seen that the near diaphragm was placed at 56 cm. from the target, and the distance between the two diaphragms was 34 cm. It should be noted that in this case the end of the lead-lined tube was closed and the near diaphragm was placed at this point. The adjustable shutters at the tube-holder opening were opened to 10 × 10 cm. to obviate any interference with the roentgen-ray beam at this point (refer to Fig. 9 for a comparison of the set-ups). The experimental procedure was the same as for the first series except that some of the numbered diaphragms were omitted. The results are shown graphically by the solid

*The straight lines in the figure will be explained later.

curves of Figure 10. The dotted curves are reproduced from Figure 9 to facilitate comparison. The two sets are plotted to the same scale and are in the proper relative positions. In Figure 11 they are plotted to different scales chosen so as to

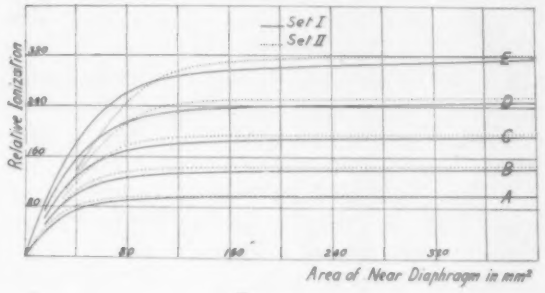


Fig. 11.

make the highest points of curves A coincide.

It will be seen that the two sets of curves have the same general shape, although the arrangement of the diaphragms was considerably different in the two cases. The straight line relations for near diaphragm apertures which are multiples or submultiples of the apertures of corresponding far diaphragms, appear also in the second set of curves (only one is shown in Fig. 10).

In order to place the two sets of curves in their proper relative positions in Figure 10, consecutive readings were taken with the same pair of diaphragms (F near and A far) but placed at the distances used for each set.* The ratio between the two readings was found to be 1.49. The distances from the glass bulb of the roentgen-ray tube to the diaphragms can be measured accurately, but the position of the target within the bulb is somewhat uncertain. It was decided, therefore, to determine by triangulation the distance of the target, and particularly the focal spot, from an assumed point of reference. This was done by using a sheet of copper with two very small pinholes 7.5 cm. apart and exposing a photographic film at a distance of 40 cm. from the copper sheet. Measuring the distance between corresponding points of the two pinhole pictures on the film, the position of the focal spot could be calculated. Independent determinations with two different distances between the copper and the film agreed closely with the "measured" distance (assuming that the target was at the center of the bulb). The

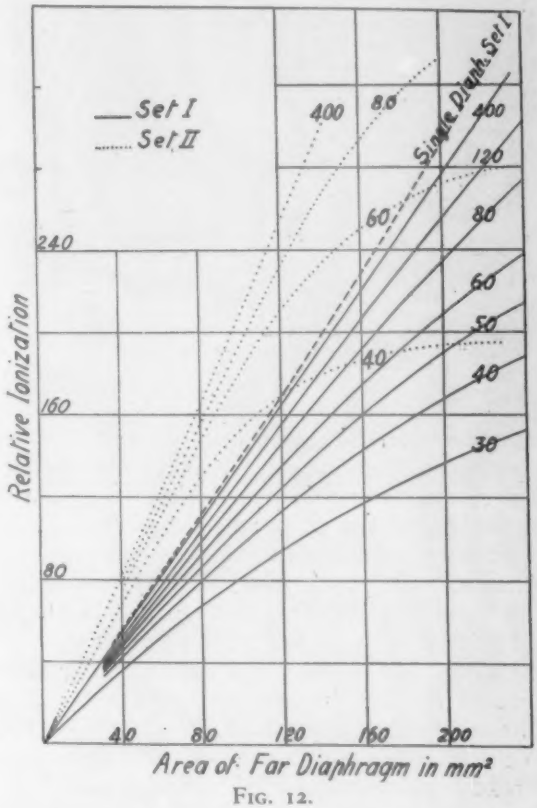


Fig. 12.

position of the diaphragms in the two sets of experiments, therefore, was determined with considerable accuracy. The far diaphragm was at a distance from the target of 108 cm. for the first set and 90 cm. for the second. The ratio of the squares of these figures is 1.44, which is somewhat different from the ratio experimentally found (1.49) for ionization readings taken with far diaphragm A in the two positions and near diaphragm F as indicated above. The discrepancy is not very large and it may be concluded that, having determined the "intensity of radiation" of a beam at a certain distance from the source, the intensity at different distances may be calculated *approximately* by the inverse square relation. For accurate work, however, it is necessary that the ionization chamber be

* To increase the precision of this determination two curves were plotted from readings obtained with diaphragms F—A, B, C, D, E, G, A in the two positions.

placed with the controlling diaphragm at the point in the radiation beam for which the "intensity" is to be determined. It should be noted in this connection that the above ratio (1.49) is a function not only of the distances involved, but also

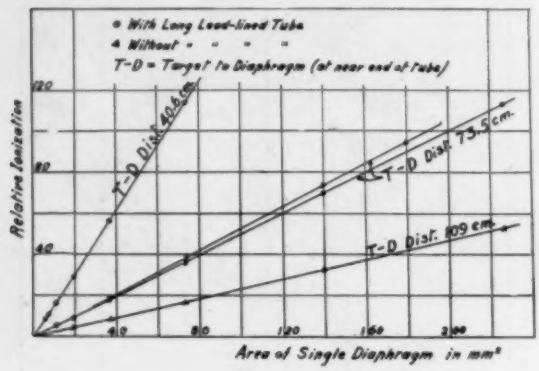


FIG. 13.

of other variables such as the sizes of the diaphragms, etc. Hence there is no simple correction factor which might be applied according to the distances considered.

From the curves of Figure 11 it may be surmised that each pair (corresponding to the same far diaphragm) becomes asymptotic. Accordingly for very large near diaphragms the same relation between the area of the far diaphragm and the ionization readings should hold for the two sets. We may check this point first with the data already presented. For this purpose we have plotted the curves of Figure 12 taking as the independent variable the area of the far diaphragm. The solid curves are for Set I and the dotted ones for Set II (q. v.). The line drawn in dashes is for the case in which no near diaphragm was used and the single diaphragm was placed at the position of the far diaphragm in Set I. Each curve is for a definite size of near diaphragm (given on the curve in square millimeters). It will be seen that in both sets the curves for small near diaphragm apertures are concave downward. For large near diaphragms (about 300 mm.^{2}) they become practically straight lines passing through the origin, and for still larger apertures (400 mm.^{2}) they become slightly concave upward. The curve for a single diaphragm, of course, is also slightly concave upward.

The conclusion to be drawn from these curves is that the ionization in the chamber is practically proportional to the area of the far diaphragm when the near diaphragm is relatively large or is absent. For this relation to hold the near diaphragm should be constant and of about the same size as the largest far diaphragm. If the near diaphragm is of the same size as each far diaphragm, the relation does not hold so closely. This may be deduced from the fact that the *straight* lines in Figure 10 do not pass through the origin. With small near diaphragms the ionization increases at a slower rate than the area of the far diaphragm, indicating that some of the radiation is blocked out. This is true even when the area of the near diaphragm is considerably larger than the "geometrical aperture" corresponding to the largest far diaphragm.

EXPERIMENTS WITH A SINGLE DIAPHRAGM

In view of the above results, it was thought desirable to obtain more data using a single diaphragm. Experiments were made with the diaphragm placed at three different distances from the target: 40.6, 73.5 and 109 cm. The position of the diaphragm with respect to the ionization chamber was also changed. This was done by changing the length of the lead-lined tube at the entrance to the chamber from 6.9 to 42.5 cm. (The figures refer to the distance from the front edge of the diaphragm to the front end of the chamber.) The results plotted to the same scale are given in Figure 13.

It will be seen that in all cases the experimental points practically fall on straight lines which pass through the origin. The lines in the figure have a very slight upward curvature for diaphragm apertures smaller than 40 mm.^{2} but are straight from there on. This shows that for diaphragms larger than 40 mm.^{2} the ionization in the chamber is proportional to the area of the aperture, irrespective of the distance from the target and the presence or absence of the long lead-lined tube. It should be noted, however, that the two curves in the center of the figure were obtained with the diaphragm at the same distance from the target, but different distances from the ionization chamber (by changing the length

of the lead-lined tube). From these we are able to determine the influence of the length of the lead-lined tube. The ionization for equal diaphragms is greater (by about 5 per cent) when the lead-lined tube is very short.

At this point we may bring out the differences between the curve for a single diaphragm given in Figure 12 and those given in Figure 13. In the case of the former the diaphragm was within the lead-lined tube in position N (Fig. 9), whereas for the experiments of Figure 13 it was always at the near end of the lead-lined tube (whether long or short). Both curves have a slight upward curvature. But in Figure 12 the curvature increases with the size of the diaphragm, whereas in Figure 13 it is present only for small diaphragm apertures. This is probably due to the fact that in the set-up of Figure 9, when the near diaphragm was absent or was large, some radiation struck the lead lining of the tube and produced secondary and scattered rays. Hence, as the size of the far diaphragm increased, more of this radiation entered the chamber.

From the data of Figure 13 we may calculate the ratios of the ionization readings for the same diaphragm apertures in different positions. They are given in Table V. For comparison we have added the ratios of the squares of the distances for the two cases.

TABLE V

Area of Single Diaphragm in Mm.²	With Lead-lined Tube			Without Lead-lined Tube		
	Distances in Cm.		Ratio of Squares	Distances in Cm.		Ratio of Squares
	40.6	73.5	3.27	73.5	109.0	2.20
	Ionization Readings		Ratio	Ionization Readings		Ratio
30	45.5	14.3	3.18	15.2	6.7	2.27
50	77.0	24.2	3.18	26.0	11.4	2.28
70	108.2	34.2	3.16	36.4	16.0	2.27
100	155.0	49.2	3.15	52.2	23.0	2.27
150	.....	.....	....	78.7	34.7	2.26
200	.....	.....	....	105.0	46.6	2.25

The ratios of the ionization readings agree quite well among themselves but they differ by about 3 per cent from the corresponding ratios of the squares of the distances. It should be noted also that this difference is in the opposite direction in the two cases. It may be that by choosing a suitable length for the lead-lined tube, a closer agreement with the inverse square relation could be obtained. This question, as well as many others, requires further experimentation.

FIG. 14.

The writer intended to include in the present paper a general discussion of the question of roentgen-ray measurements as regards the establishment of suitable standards in the light of the results given here, and what has appeared in the recent publications of other investigators. Since time does not permit an extended discussion, for the present we shall limit our remarks to an important point brought out by some of our experiments.

The curves given in Figures 9 to 12 show that in general the "near" diaphragm has a marked influence on the amount of radiation entering the chamber through the far diaphragm. As would be expected, this is particularly true when the near one is smaller than the far one, but it should be noted that the near diaphragm may be considerably larger than the "geometrical aperture" determined by the inverse square relation, and still control to a large extent the radiation entering the chamber. Thus a variation of the aperture of the near diaphragm from the value given by the inverse square relation to the size of the far one, may make a difference of 200 to 300 per cent in the

beam of radiation (keeping the far diaphragm constant). The difference is greater for far diaphragms of small aperture than for those of large size, but it is always very marked. From this result it is evident that when more than one diaphragm is used, the measurement of the "intensity" of a beam of radiation depends to a large extent on the sizes and positions of all the diaphragms. This may account for the discrepancies occurring in measurements of roentgen-ray beams in terms of the R-unit which have been reported in the literature.

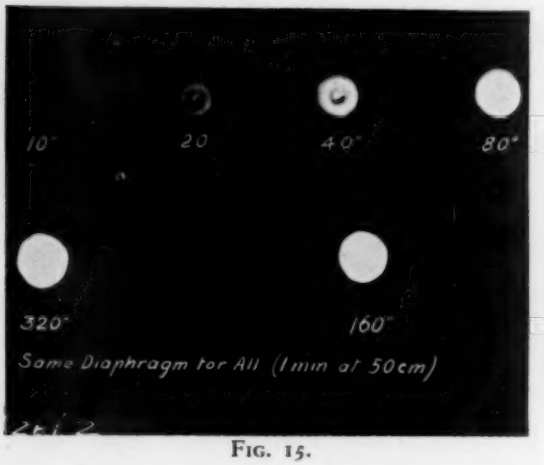


FIG. 15.

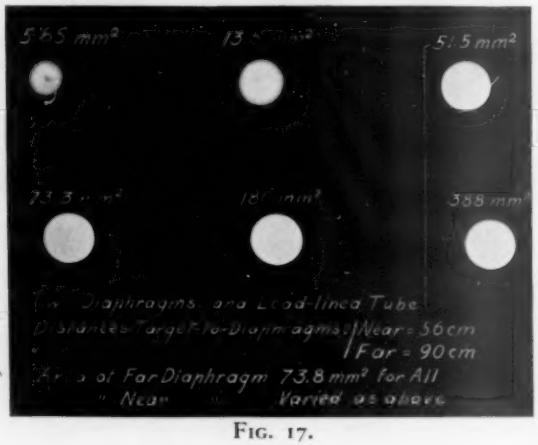


FIG. 17.

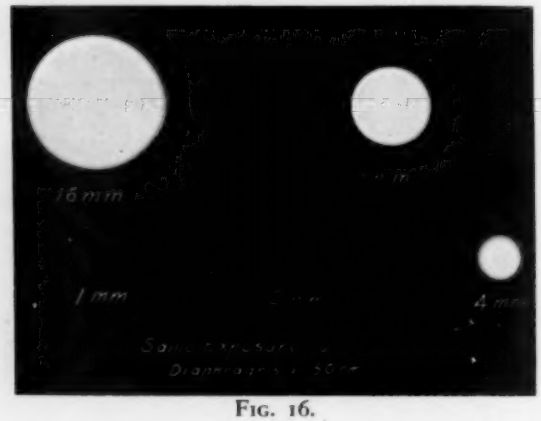


FIG. 16.

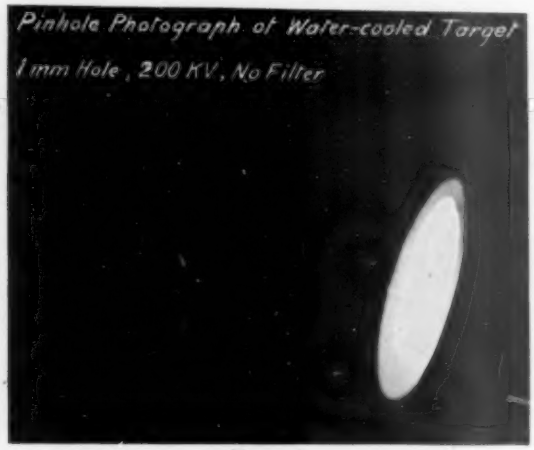


FIG. 18.

Such discrepancies can be avoided, of course, by reaching an agreement on the number, sizes, and positions of the diaphragms to be used. Similarly, other possible discrepancies may be avoided by strict specifications for the whole experimental set-up. This may be the only practical solution at the present time, but one should always consider the significance of measurements made under more or less arbitrary conditions. The problem is much more complex than is generally assumed, and a great deal of work remains to be done. Accordingly we prefer not to make any definite recommendations at this time.

The writer wishes to acknowledge his indebtedness to his assistants in the Physical Laboratory, whose whole-hearted co-operation made this work possible. Particular thanks are due to Mr. Edwin Lobley, who collaborated with the writer throughout the course of the experiments.

APPENDIX

The "desirability" of preventing "stem" radiation from entering the chamber has been discussed by some authors, and the use of a second diaphragm has been advocated on this basis. We feel that if this is done, measurements of a beam of radiation are made under artificial conditions, which do not ordinarily exist when the beam is used for practical purposes. Furthermore, since the area of the focal spot in deep therapy Coolidge tubes is rather large (about 110 mm.^{2}), when small diaphragms are used, the distribution of radiation over the cross section of the beam must be influenced by the size, position, and other arrangement of the diaphragms. If one diaphragm is used, then there is some radiation considerably beyond the main beam. In this case the ionization chamber should be large enough to prevent this radiation from striking the electrodes or inner walls of the chamber.

Experiments were begun with the idea of determining the distribution of radiation in a plane perpendicular to the beam, after passing through different diaphagm arrangements. A photographic method was chosen for this purpose. In addition to visual observations of the films exposed under different conditions, it was planned to use a photoelectric "intensitometer" to obtain quantitative data. Since time did not permit the completion of this work, we are appending a few photographs, which give an idea of the results to be expected. Figures 14, 15, 16 and 17 were taken with the roentgen-ray tube used in the ionization experiments, Figures 18, 19 and 20 with a water-cooled deep therapy Coolidge tube, in which the focal spot is much larger.

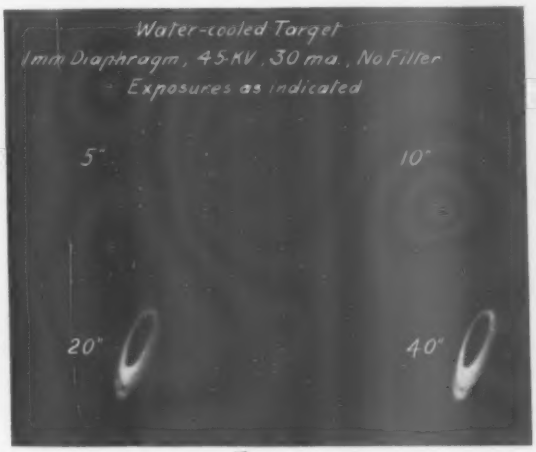


Fig. 19.

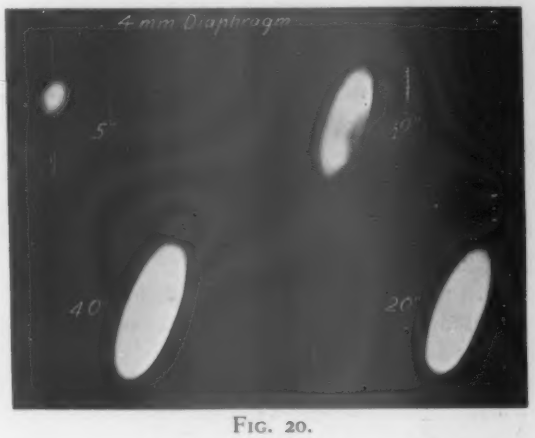


Fig. 20.

A COMPARISON OF PRACTICAL METHODS OF MEASURING ROENTGEN-RAY QUALITY FOR THERAPY

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A NUMBER of methods are used to determine the quality of the roentgen radiations used in therapy. These vary greatly both in simplicity and accuracy, from the measurement of the spark gap and filter to the spectrometric investigation of the output of the roentgen tube. A study of the spectrum gives, of course, an accurate knowledge of the radiation. But it necessitates the use of delicate instruments by highly trained workers, and is impractical for the average clinical roentgen-ray department. Moreover, such accurate information is probably not necessary from a therapeutic point of view. On the other hand, spark gap measurements are simple, and require no complicated apparatus. Such measurements, however, determine only the peak voltage, or minimum wave length, which may carry only a very small part of the total energy, depending on the wave form and the phase relations between voltage and current.

Between these two extremes come such methods as measurements of absorption coefficients in various substances, determination of half-value layers and determination of effective wave length. The coefficient of absorption represents the percentage of the incident radiation which is absorbed (or scattered) per unit thickness of filter. The half-value thickness of any filter is the thickness which reduces the incident radiation to 50 per cent of its value. The effective wave length as defined by Duane,[1] who first proposed its use, is the wave length of monochromatic roentgen ray that has the same absorption as the whole beam of rays in any particular case. The method of determining it consists in measuring the fraction of the radiation that passes through a given thickness of copper or aluminum. The relation between this fraction and the effective wave length for 1 mm. of copper or 4 mm. of aluminum is given in curves published by Duane,[1] made from spectrometric measurements.

Since a statement of quality of radiation as determined by any of these three methods contains neither the voltage at which the radiation is produced, nor the filter through which it passes, it would seem that the actual quality in different cases might be very different. For example, a highly filtered radiation at comparatively low voltage might be reduced to the same fraction of its intensity in passing through a millimeter of copper as a lightly filtered radiation at a higher voltage. The effective wave length would then be the same, whereas the radiations would be quite different.

The objects of the present investigation were: (*a*) to establish series of radiations that were equivalent from the point of view of the above definitions, and to study their behavior, and (*b*) to compare by these methods the qualities of the radiations produced by different therapy machines operated at the same voltage and filtration.

The first part of the work was done with a mechanical rectifier type machine having a water-cooled Coolidge tube operating at 30 ma. Absorption curves for copper and aluminum were made for 200, 175, 150, 125, and 100 kv. The voltages were measured by a sphere gap, and the ionization by means of an electroscope and small ionization chamber of the Friedrich type. The curves were plotted (Fig. 1) and equivalent series of radiations determined as follows: It was decided to find the series having the same absorption coefficient as measured in the first 0.1 mm. of copper, the series having the same half-value layer in copper, and the series having the same effective wave length as measured in 1.0 mm. of copper. Radiation at 200

kv. with a filter of 0.2 mm. of copper was chosen as the starting point. This was selected arbitrarily as a reasonable filter to use with the highest voltage. Having chosen the starting point, the equivalent series had to be found by a method of trial and error, but the process is not laborious. The following results were obtained (Table I):

TABLE I

Voltage, Kv.	Thickness of Copper Filter to Give the Same		
	Absorption Coefficient in 0.1 Mm.	Half-Value Layer	Effective Wave Length
	2.03 mm.$^{-1}$	0.47 mm.	0.176 Å
200	0.20	0.20	0.20
175	0.22	0.24	0.28
150	0.28	0.30	0.46
125	0.40	0.54	0.76
100	0.81	1.20	1.50

Of course the intensities of the radiations in any series differ greatly among themselves. Decrease of voltage and increase of filter make each one less than those preceding it. The values as determined by the ionization measurements are given in Table II.

TABLE II

Voltage, Kv.	Radiation Intensity for Equal		
	Absorption Coefficient	Half-value Layer	Effective Wave Length
200	100	100	100
175	67	64	60
150	39	37	28
125	17	13	9
100	3	2	1

From Table I it is apparent that the greater the thickness of copper used as the determining factor, the greater are the differences among the filters in the series. This is not dependent on the method used, for they are all inherently the same. Table II shows the increase in the range of intensities as the determining filter is increased.

It is obvious that the radiations in all of these sets cannot be actually equivalent, since the first members of all three are the same, and the others are different. The variations may be investigated by measuring the absorption of the radiations in each series in some substance. The material

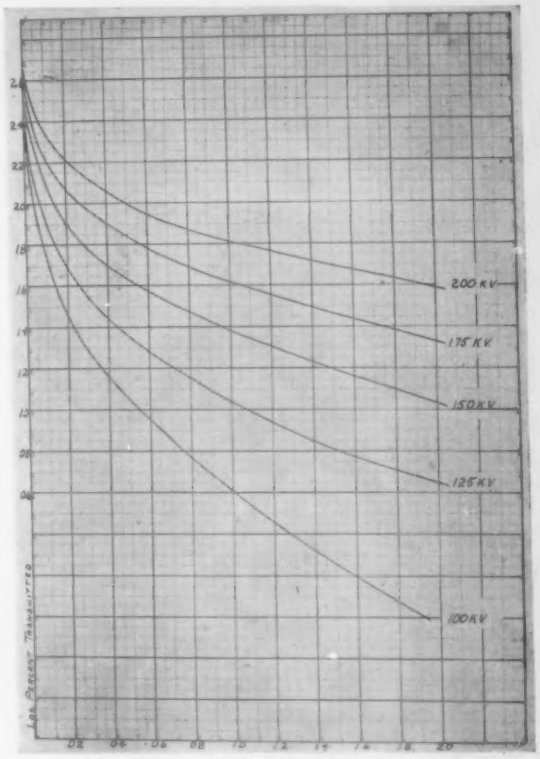

FIG. 1. Copper absorption curves for different voltages.

already at hand enables us to determine the absorption curves for all these radiations in copper. Measurements were made of their absorption in lead, aluminum, and pure gum rubber. This last material, being composed mainly of elements of low atomic weight, may be considered comparable to tissue. Comparisons of these different series of "equivalent" radiations may be facilitated by tabulating these absorption measurements, which is done in Table III. These measurements do not include the 100 kv. radiation; its intensity was so small compared with the others that the time necessary to make the measurements would have been very long, and the results less accurate than the others. The 175 kv. radiation was omitted for the series having

TABLE III

A. Absorption in Rubber

Rubber, mm.	Percentage Radiation Transmitted				
	1. Effective Wave Length the Same				Variation between Extremes Per Cent
	200 kv. 0.20 mm. Cu	175 kv. 0.28 mm. Cu	150 kv. 0.46 mm. Cu	125 kv. 0.76 mm. Cu	
0	100	100	100	100	
5	92.0	92.2	93.2	94.0	2
10	84.5	84.7	85.0	87.0	3
20	72.3	73.3	74.3	76.0	5
30	62.5	63.5	64.0	66.0	6
40	54.4	55.6	57.1	58.5	7
50	47.4	48.0	49.5	50.2	6
	2. Half-value Layer the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.24 mm. Cu	150 kv. 0.30 mm. Cu	125 kv. 0.54 mm. Cu	
0	100	100	100	100	
5	92.0	90.4	91.2	92.5	1
10	84.5	83.0	84.2	85.6	2
20	72.3	72.4	72.0	73.8	2
30	62.5	62.2	63.0	63.7	2
40	54.4	54.2	53.5	55.9	2
50	47.4	46.5	47.0	47.7	1
	3. Absorption Coefficient the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.22 mm. Cu	150 kv. 0.28 mm. Cu	125 kv. 0.40 mm. Cu	
0	100	100	100	100	
5	92.0	.....	90.1	92.2	1
10	84.5	.....	83.5	83.5	1
20	72.3	.....	71.9	71.9	1
30	62.5	.....	62.0	62.0	1
40	54.4	.....	54.7	54.7	1
50	47.4	.....	46.5	46.5	1

TABLE III (*Continued*)

B. Absorption in Aluminum

Alumi-num mm.	Percentage Radiation Transmitted				
	1. Effective Wave Length the Same				Variation between Extremes Per Cent
	200 kv. 0.20 mm. Cu	175 kv. 0.28 mm. Cu	150 kv. 0.46 mm. Cu	125 kv. 0.76 mm. Cu	
0	100	100	100	100	
1.1	90.3	91.6	92.0	91.8	2
3.3	77.0	78.7	78.5	79.0	3
6.0	64.0	66.0	65.8	67.0	5
9.7	50.3	52.4	52.0	53.4	7
16.2	34.8	36.6	36.7	36.3	6
22.7	25.0	26.0	26.3	26.7	7
	2. Half-value Layer the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.24 mm. Cu	150 kv. 0.30 mm. Cu	125 kv. 0.54 mm. Cu	
0	100	100	100	100	
1.1	90.3	88.1	89.5	89.4	1
3.3	77.0	75.8	75.8	77.0	1
6.0	64.0	62.4	62.0	64.9	1
9.7	50.3	49.8	49.8	50.6	1
16.2	34.8	33.8	33.5	34.0	2
22.7	25.0	23.8	23.0	24.3	3
	3. Absorption Coefficient the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.22 mm. Cu	150 kv. 0.28 mm. Cu	125 kv. 0.40 mm. Cu	
0	100	100	100	100	
1.1	90.3	.....	88.8	87.5	3
3.3	77.0	.....	74.1	73.7	5
6.0	64.0	.....	60.7	61.6	4
9.7	50.3	.....	47.2	47.0	7
16.2	34.8	.....	33.3	31.3	11
22.7	25.0	.....	22.5	20.4	22

absorption coefficients the same, because the 0.22 mm. copper filter required was not available. Its lack does not greatly lessen the value of the information since it is an intermediate radiation.

The data here accumulated indicate how much difference may exist among radiations which are equivalent by definition. They also show that the difference found depends on the medium used to test the radiations. The differences shown by absorption in rubber are much less than those shown by absorption in lead. The set having the same absorption coefficient referred to 0.1 mm. of copper are absorbed identically in rubber. That is, with reference to absorption in an organic material, they actually are equivalent. But with reference to absorption in metals, they are not equivalent, and the apparent difference

TABLE III (*Continued*)

c. Absorption in Copper

Copper, mm.	Percentage Radiation Transmitted				Variation between Extremes Per Cent
	1. Effective Wave Length the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.28mm. Cu	150 kv 0.46mm. Cu	125 kv. 0.76mm. Cu	
0	100	100	100	100	
0.1	81.9	85.0	86.0	87.0	6
0.2	69.1	73.3	75.6	75.0	9
0.4	53.7	56.5	61.0	59.0	13
0.6	44.9	46.8	49.5	48.8	10
0.8	39.3	39.9	40.8	40.8	4
1.0	35.1	34.8	35.2	35.2	1
1.25	31.1	29.6	28.9	30.1	8
1.50	27.4	25.2	23.0	.....	19
	2. Half-value Layer the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.24 mm. Cu	150 kv. 0.30 mm. Cu	125 kv. 0.54 mm. Cu	
0	100	100	100	100	
0.1	81.9	83.8	82.5	85.5	5
0.2	69.1	72.0	70.3	74.0	7
0.4	53.7	55.0	54.8	55.5	4
0.6	44.9	44.8	44.3	43.5	3
0.8	39.3	38.2	35.8	34.1	15
1.0	35.1	33.1	29.6	29.4	20
1.25	31.1	27.9	24.6	24.3	24
1.50	27.4	23.8	20.4	20.6	33
	3. Absorption Coefficient the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.22 mm. Cu	150 kv. 0.28 mm. Cu	125 kv. 0.40 mm. Cu	
0	100	100	100	100	
0.1	81.9	82.0	81.5	81.5	1
0.2	69.1	70.8	69.4	69.1	2
0.4	53.7	53.8	53.6	51.2	5
0.6	44.9	43.7	43.1	45.7	6
0.8	39.3	37.0	35.0	30.7	27
1.0	35.1	32.1	28.8	25.5	37
1.25	31.1	27.1	24.0	20.8	50
1.50	27.4	23.0	19.8	17.3	59

is greater, the greater the density and atomic number of the metal used. The set having the half-value thickness of 0.47 mm.

TABLE III (*Continued*)

d. Absorption in Lead

Lead, mm.	Percentage Radiation Transmitted				Variation between Extremes Per Cent
	1. Effective Wave Length the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.28 mm. Cu	150 kv. 0.46 mm. Cu	125 kv. 0.76 mm. Cu	
0	100	100	100	100	
0.1	43.4	43.8	47.5	50.2	16
0.2	24.0	24.0	25.4	27.0	12
0.3	14.5	14.4	14.8	16.0	11
0.4	8.8	8.8	9.0	10.0	13
0.5	5.8	5.6	5.7	6.2	11
	2. Half-value Layer the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.24 mm. Cu	150 kv. 0.30 mm. Cu	125 kv. 0.54 mm. Cu	
0	100	100	100	100	
0.1	43.4	42.3	41.4	45.9	11
0.2	24.0	21.6	21.4	22.7	12
0.3	14.5	13.0	12.4	13.9	17
0.4	8.8	7.9	7.6	8.4	11
0.5	5.8	4.9	4.6	5.4	26
	3. Absorption Coefficient the Same				
	200 kv. 0.20 mm. Cu	175 kv. 0.22 mm. Cu	150 kv. 0.28 mm. Cu	125 kv. 0.40 mm. Cu	
0	100	100	100	100	
0.1	43.4	.....	42.2	43.7	3
0.2	24.0	.....	21.4	20.9	15
0.3	14.5	.....	12.6	12.0	20
0.4	8.8	.....	7.6	7.6	16
0.5	5.8	.....	4.6	4.6	26

of copper are absorbed in the same manner in aluminum; they are equivalent according to this criterion, but not when tested with substances of greater or less density than aluminum. The set having the same equivalent wave length as determined by absorption in 1 mm. of copper are not absorbed in the same manner by any of the testing substances. They are most nearly the same for lead, but even here there are large differences.

The irregular variations found in the

copper absorption values are due to the manner in which the equivalent radiations were selected. For the effective wave length to be the same, the percentage reading for the copper filter must be the same for no additional filter, and for 1.0 mm. additional

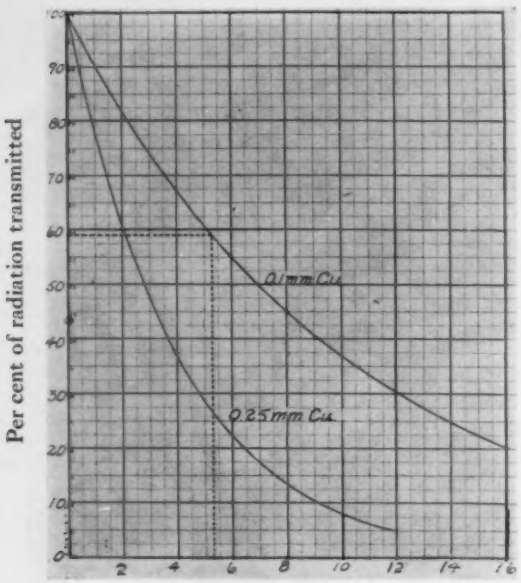

FIG. 2.

copper; for the same half-value layer, the values must be alike for 0.47 mm. additional copper. Therefore the curves, if plotted, must come together at the corresponding points.

From these data we may conclude that it is not sufficient to define radiation by any of the schemes here tested, without other specifications. Additional statements of the voltage and the thickness of copper used in testing the quality are necessary.

When the radiation is to be used in therapy, its absorption in a substance of low atomic weight is of chief interest. If radiations are to be equivalent when absorbed in such a substance, they must have the same absorption coefficient in a thin layer of copper.

The finding of such an absorption coefficient necessitates only two measurements—the electroscope readings before and after the insertion of the measuring filter (0.1 mm. copper). The required coefficient is then obtained from the formula

$$\mu = \frac{\log I_0 - \log I}{d \log e}$$

where μ is the absorption coefficient;

I_0 is the initial radiation;

I is the radiation after the insertion of the filter;

d is the thickness of the absorbing layer;

e is the base of natural logarithms.

If the testing layer of copper is to be 0.1 mm., I_0 is taken as 100 per cent, and I is expressed in percentage of I_0, and the formula becomes

$$\mu = \frac{2 - \log I}{0.0434} \text{ per mm.}$$

From this equation a curve can be constructed for obtaining the value of μ as soon as I has been measured. This is the upper curve of Figure 2. The method of using it is illustrated by the following example:

Electroscope reading without measuring filter..... 34.6 sec.
with measuring filter..... 59.8 sec.

$$I = \frac{34.6}{59.8} \times 100 = 59$$

The value of μ on the curve corresponding to 59 on the I scale is 5.3, as indicated on the figure.

The lower curve of this figure gives the absorption coefficients if the testing layer of copper is 0.25 mm. thick.

There seems to be, however, a general inclination to express the quality of radiation in terms of effective wave length. Duane recommends this because it may be determined by making only one additional measurement. This, however, is also true of the absorption coefficient as just discussed. We have just seen that effective wave length, *as measured by absorption in 1.0 mm. of copper* is not very satisfactory for therapy radiations. Richtmyer and Grant[5] have derived a formula relating wave length and absorption coefficient of monochromatic radiation, which may be used in the same way as Duane's monochromatic absorption curves, to find the "effective wave length" of a heterogeneous beam of rays. This formula is

$$\frac{\mu}{\rho} = 0.00658N^3\lambda^3 + 0.155$$

where μ is the absorption coefficient per cm.,

ρ the density of the absorber,

N the atomic number of the absorber,

λ the effective wave length.

For any given absorber, of course, ρ and N are constants; μ would be constant also if we were actually dealing with monochromatic radiation. But for the heterogeneous mixture of rays used in therapy, the value obtained for μ depends on the thickness of the absorber. For, as this is increased, the emerging radiation becomes harder, the value of μ and consequently of λ, becomes less. This is easily demonstrated by finding the values of λ for the three measuring thicknesses of copper used in this work, for one of the radiations, say 200 kv. and 0.2 mm. copper filter. For this radiation 0.1 mm. additional Cu transmitted 81.9 per cent,

0.47 mm. Cu transmitted 50.0 per cent,

1.0 mm. Cu transmitted 35.1 per cent.

These percentages are the values for I in the general formula for μ given above, the thicknesses of copper absorber (0.1, 0.47, 1.0) being the corresponding values of d, and I_0 being always 100. On solving this equation for the three absorbers, we find:

for 0.1 mm. Cu, μ = 20.3 per cm.
for 0.47 mm. Cu, μ = 12.9 per cm.
for 1.0 mm. Cu, μ = 7.0 per cm.

Putting these values for μ in Richtmyer's equation and solving for λ we obtain:

for 0.1 mm. Cu, λ_{eff} = 0.235 Å
for 0.47 mm. Cu, λ_{eff} = 0.208 Å
for 1.0 mm. Cu, λ_{eff} = 0.182 Å

Yet this is actually the same radiation throughout. This shows definitely that the effective wave length* is not an actual measure of the quality of the radiation employed, and emphasizes the fact that when it is used, the thickness of testing filter must be stated.

From this formula, curves may be developed relating the percentage of radiation transmitted and the effective wave length, for any filter thickness chosen as standard. The values for 1.0 mm. of copper agree with Duane's curve, within less than 3 per cent. The curves for 0.1 mm. and 0.25 mm. of copper are given in Figure 3. As shown above, they will give different λ_{eff} values for the same radiation. For the radiation used in the preceding example, 0.1 mm. of copper transmitted 81.9 per cent. From the curve, the effective wave length corresponding to this is 0.235 Å. Of this same

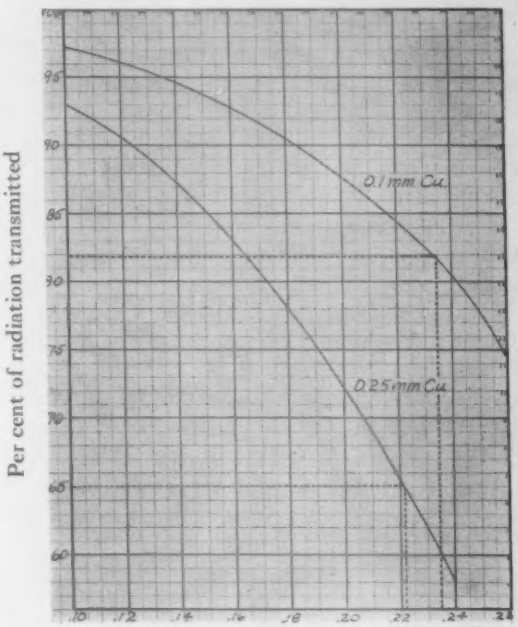

FIG. 3.

radiation, 0.25 mm. of copper transmitted 65 per cent. From the curve for 0.25 mm. this corresponds to an effective wave length of 0.222 Å; 1.0 mm. of copper transmitted 35.1 per cent of this same radiation, and Duane's curve gives an effective wave length of 0.176 Å. This differs from the calculated value (0.182 Å) by 3 per cent. (There is in this part of the curve, an irregularity which does not agree with the theory, nor with later experimental values, and is responsible for this discrepancy.)

For four different testing thicknesses of copper we therefore have four widely different values for the effective wave length of the same radiation:

For 0.10 mm. copper.... 0.235 Å
For 0.25 mm. copper.... 0.222 Å
For 0.47 mm. copper.... 0.208 Å
For 1.00 mm. copper.... 0.182 Å

Each of these refers to a definite thickness of the testing filter. From this it is evident

* This statement applies also to absorption coefficient.

that a statement of the effective wave length *alone* does not define the quality of a radiation. *When radiation is described by its effective wave length, or any other quantity determined by absorption measurements, the thickness of the absorbing layer of copper used for the determination must be stated.*

We have shown that radiations of the type here considered, whose equivalence is established by testing with a small thickness of copper are absorbed in the same manner in organic substances, while those whose equivalence was determined by testing with larger thickness were not. We therefore recommend the use of the curves of Figure 3 for determining the effective wave length of radiations used in therapy.

Duane also gives curves for determining the effective wave length by measuring the absorption in 4 mm. of aluminum, and by finding the thickness of aluminum having the same absorption as 1 mm. of copper. The radiations found equivalent by absorption in 1 mm. of copper were compared by these methods. The result is given in Table IV.

TABLE IV

Radiation		Wave Length Determined by		
Kv.	Mm. Cu	Absorption in 1 Mm. Cu	Absorption in 4 Mm. Al	Mm. Al Equiv. to 1 Mm. Cu
200	0.20	0.176 Å	0.192 Å	0.173 Å
175	0.30	0.176 Å	0.187 Å	0.175 Å
150	0.46	0.176 Å	0.180 Å	0.174 Å
125	0.76	0.176 Å	0.174 Å	0.173 Å

These results are such as would be expected from the present work. Measuring absorption in 4 mm. of aluminum is analogous to measuring it in less than 1 mm. of copper, since, for rays of the quality here used, about 17 mm. of aluminum absorbs as much as 1 mm. of copper. The effective wave length as determined by absorption in 4 mm. of aluminum shows a decrease in the direction of radiation with lower voltage and higher filtration. For these wave lengths to be the same, the primary filters for the lower voltages would evidently have to be decreased to permit the passage of a larger proportion of long wave length components. Reference to Table 1 shows that when equivalent radiations are established by smaller testing layers of copper, the filters for the lower voltages are correspondingly less. No tests have been made of comparative absorption of radiations having equivalent wave lengths as determined by absorption in aluminum.

It would be expected that by finding the thickness of aluminum equivalent to 1 mm. of copper, the same results would be obtained as for absorption in 1 mm. of copper.

Holthusen and Gollwitzer[2] recommend the half-value layer in copper as a standard. But their experimental work was done with two radiations whose half-value layer was 0.178 mm. of copper—75 kv., 0.25 mm. Cu filter and 180 kv., 1.0 mm. Al filter. This half-value layer is within the range of copper thickness we recommend for quality determinations, but for the radiations used in deep therapy the half-value layer is always greater than this. We have shown that greater thicknesses of copper are not as satisfactory for defining therapy radiations, and that, therefore, the half-value layer is not as good a criterion as one depending on a smaller copper filter. It may be mentioned in passing that these authors investigated the equivalence of their radiations by absorption in water, and by various biological means, and found no difference in the two, for the same doses in R units.

Meyer and Braestrup[4] prefer the half-value layer in aluminum as the standard for quality determination. But they give no comparative data on the behavior of radiations having the same quality according to their definition. The set of radiations which we found to be equivalent as regards absorption in rubber have the following half-value layers in aluminum:

200 kv., 0.20 mm. Cu.... half-value layer 9.7 mm. Al
150 kv., 0.28 mm. Cu.... half-value layer 9.0 mm. Al
125 kv., 0.40 mm. Cu.... half-value layer 8.7 mm. Al

These show an extreme variation of more than 10 per cent, whereas the absorption coefficients of these radiations referred to 0.1 mm. of copper were identical. Therefore it would seem that, for purposes of

comparing radiations for absorption in a biological material, the half-value layer in aluminum is not as satisfactory as the absorption coefficient (or effective wave length) referred to a thin layer of copper.

For the comparison of therapy machines, two mechanical rectifier machines as different as possible were selected. One (A) had very short contacts on the rectifier, and operated an air-cooled tube at 4 ma., while the other (B) had very long contacts and operated a water-cooled tube at 30 ma. Both tubes were run at 200 kv., as checked by a sphere gap.

Three sets of comparisons were made. Copper absorption curves were made for the two machines, measurements being made as described in the first part of this paper. The copper curves were found to be practically coincident. This means that equivalent filters would be the same whatever the testing thickness of copper—or in other words, that the same thickness of copper should affect the radiation from each machine in the same manner. Accordingly a filter of 0.5 mm. of copper was used, and the absorption of the radiations transmitted thereby measured for lead and for rubber. The curves for rubber were found to be coincident, but those for lead were found to differ by 10 per cent for more than 0.25 mm. of lead. The machine having the long contacts emitted a radiation that was more strongly absorbed in this case. This might be expected, since the long contacts permit the inclusion of more low voltage components in the radiation mixture. These curves are all shown in Figure 4.

This comparison indicates that, as measured by absorption in rubber (or tissue) a statement of the voltage and filter for machines of the mechanical rectifier type, is sufficient to define the radiation. However, it is well known that voltage measurements as made at present are subject to great inaccuracy. The same sphere gap, in the hands of different operators, may give quite different results on the same voltage, and results obtained with different gaps used by the same operator may differ considerably, due to difference in size and surface of the spheres. The spectrographic method of measuring voltage always gives results lower than the spark gap. Therefore, in view of this uncertainty in voltage measurements, a statement of quality as referred to absorption in a thin layer of copper is desirable, in addition to specification of voltage and filter.

Jacobi and Liechti[3] extended the work of

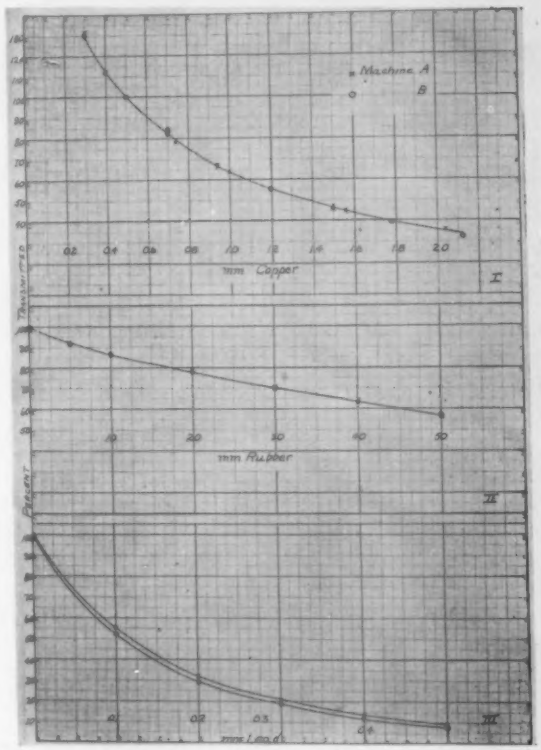

Fig. 4. Absorption curves for two therapy machines.
I. Copper.
II. 0.5 mm. copper plus rubber.
III. 0.5 mm. copper plus lead.

Holthusen and Gollwitzer[2] to a comparison of radiations from a wide variety of apparatus—constant, pulsating, and sinusoidal potentials—and found that for all of these, with the same voltage (measured spectrographically) and filter, the half-value layer in copper was the same. They compared their radiations by measuring the depth dose in water, and found that this was not necessarily the same for the same half-value layer, but depended also on what they call the "homogeneity," which is a function of the filter and voltage. This corresponds with our finding that equivalence as determined by absorption in 1 mm. copper did not insure equivalence as regards absorption in rubber. For

radiations with a half-value layer in the neighborhood of 1 mm. of copper, they find a somewhat greater depth dose for the one with the lower voltage and higher filter. This agrees with our data in the first part of Table III, where the effective wave length is measured by absorption in 1 mm. of copper.

SUMMARY

Three methods of quality determination of roentgen rays were compared quantitatively. These are: absorption coefficients referred to 0.1 mm. of copper, half-value layer in copper, effective wave length as determined by absorption in 1 mm. of copper.

By each of these standards, a set of four equivalent radiations was established, at voltages from 125 to 200 kv., with the necessary copper filters to correspond to 0.20 mm. for 200 kv. in each case.

The absorption of these "equivalent" radiations was measured in lead, copper, aluminum, and rubber, the last being used as an approximation to tissue.

Radiations established as equivalent by the absorption coefficient referred to 0.1 mm. of copper were found to be equivalent as regards their absorption in rubber; those whose equivalence was established by greater testing thicknesses of copper were found equivalent as regards their absorption in correspondingly denser substances.

Absorption coefficients or effective wave lengths may be measured with reference to any desired thickness of copper as a standard. Each different thickness will give different results. Therefore when either absorption coefficient or effective wave length is given to define the quality of radiation, the thickness of copper used for the determination must be stated.

Curves are given for finding either the absorption coefficient or the effective wave length, when the measuring thickness of copper is 0.1 to 0.25 mm. Curves for any other thickness of copper can be obtained from Richtmyer's formula.

Radiations from two different makes of mechanical rectifier machine were compared. For the same voltage and filter, the quality as determined by any method involving absorption in copper was the same, and these equivalent radiations were absorbed equally in rubber.

It is therefore concluded that for machines of the mechanical rectifier type, the quality is sufficiently determined by a statement of the voltage and filtration. However, difficulties in the exact measurement of voltage make it desirable to add some further specification. For this purpose, the absorption coefficient referred to from 0.1 to 0.25 mm. of copper, or the effective wave length as determined by absorption in such a thickness is recommended. Either of these necessitates the making of only one additional measurement.

The writer wishes to express her appreciation to Dr. G. Failla for his suggestions with regard to this problem, and to his continued interest during the progress of the work.

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Information of interest to all readers will be found on page ii.

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EDITORIAL

ROENTGENOSCOPY BY TECHNICIANS

RESOLUTIONS recently adopted by the Chicago Roentgen Society point to a practice that no roentgenologist worthy the name could countenance. It is hardly conceivable that any physician would rely upon roentgenoscopic observations made by a person without medical training. If roentgenoscopy by technicians has become a common practice it must be due to failure of physicians to realize the implications and dangers of such procedure.

The general attitude of the medical profession is now to recognize the practice of roentgenology as the practice of medicine. This is true whether it is practiced by specialists or by internists and other physicians who have trained themselves to use the roentgen ray for the diagnosis and treatment of disease. Certain parts of roentgenological practice are entirely technical such as the actual making of exposures and developing films, and they may with advantage be delegated to non-medical technicians. When the results of this technical work are to be interpreted into the terms of pathology it is obvious that a knowledge of pathology and of clinical medicine are essential. It is plain, therefore, that roentgenoscopy must be done by the physician himself since the interpretation must be made at the time of observation of the screen image. To depend upon the observation of a technician for roentgenoscopic findings would be analogous to depending upon physical findings obtained by a non-medical person by means of inspection, percussion, palpation or auscultation. It does not seem to be generally understood that roentgenoscopy requires much experience in order to make it of real value. Even the inexperienced physician is prone to think that looking upon an image of the chest upon a fluorescent screen is the same as "looking into the chest." He loses sight of the fact that what he sees upon the screen is only a composite image of structures of differing densities which lie in a number of different planes. A too common mistake of the inexperienced roentgenoscopist is to believe that a chest which shows no evidence of disease upon the screen may be dismissed as a normal chest. Everyone of experience knows that small areas of infiltration which may be discovered upon good films will escape even the most experienced roentgenoscopists.

If even well-trained physicians find difficulty in interpreting roentgenoscopic images how little dependence can be placed upon the observations of untrained technicians. The fact is that roentgenoscopy is a complicated procedure requiring much experience. Observations thus made must be carefully interpreted and especially must they be correlated with the history and the clinical aspects of the case. Such observations must therefore necessarily be made only by those with medical training.

The resolutions adopted by the Chicago Roentgen Society are as follows:

WHEREAS, it is currently reported, that efforts are being made to permit and to induce technicians to do fluoroscopy, and make fluoroscopic or roentgenoscopic examinations of patients, and

WHEREAS, it is recognized, that fluoroscopy or roentgenoscopy requires a most thorough knowledge of physiological and pathological roentgenologic findings, along with a thorough knowledge of general medicine, and

WHEREAS, it is for the best interest of the public, and more particularly the patients who are in need of fluoroscopic or roentgenoscopic examinations, that these examinations be made only by persons whose training and education properly fit them to make the same, therefore, be it

RESOLVED, by The Chicago Roentgen Society, that it is our unbiased opinion and

judgment, that fluoroscopic or roentgenoscopic examinations should be made by graduates in medicine only, and that no such examinations be made or be permitted to be made by any technicians, except they be physicians, and it is further

RESOLVED, that the Council on Medical Education and Hospitals of The American Medical Association be, and are hereby urgently requested to make it a requirement for approval for hospitals and roentgen laboratories, THAT NO TECHNICIANS ARE PERMITTED TO MAKE FLUOROSCOPIC OR ROENTGENOSCOPIC EXAMINATIONS, and it is further

RESOLVED, that copies of these resolutions be sent to the Editors of "Radiology," and the "American Journal of Roentgenology" and to the Secretary of The Chicago Medical Society for publication, and to the Council on Medical Education and Hospitals of the American Medical Association, and to the American College of Surgeons.

Subscribers to THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY *visiting New York City, are invited to make the office of* THE JOURNAL (*76 Fifth Avenue, New York*) *their headquarters. Mail, packages or bundles may be addressed in our care. Hotel reservations will gladly be made for those advising us in advance; kindly notify us in detail as to requirements and prices. List of operations in New York hospitals on file in our office daily.*

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this column solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. John T. Murphy, 421 Michigan Ave., Toledo, Ohio.
Thirtieth annual meeting, 1929: To be announced.

AMERICAN COLLEGE OF RADIOLOGY
Secretary, Dr. Albert Soiland, 1407 S. Hope St., Los Angeles, Calif.
Annual meeting, Portland, Oregon, 1929.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. Fred M. Hodges, 801 West Grace St., Richmond, Va.
Annual meeting, Portland, Oregon, July 8–12, 1929.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Dr. Robert J. May, St. Luke's Hospital, Cleveland, Ohio.
Fifteenth annual session, 1929: To be announced.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
Secretary, Dr. W. S. Lawrence, Medical Arts Bldg., Memphis, Tenn.

BUFFALO RADIOLOGICAL SOCIETY
Secretary-Treasurer, Dr. Joseph S. Gian-Franceschi, 610 Niagara St.
Meets second Monday of each month except during the summer months, the place of meeting to be selected by the host.

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. W. T. Bronson, Englewood Hospital.
Meets monthly on second Thursday from October to May (except during month of December) at Virginia Hotel. Dinner at 6 P.M., scientific session at 8 P.M.

CLEVELAND RADIOLOGICAL SOCIETY
Secretary, Dr. Harry L. Farmer, 2930 Prospect Ave.
Meetings are held at 6 o'clock at the University Club, on the fourth Monday evening of each month from September to April, inclusive.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. O. J. Shore, 2033 Park Ave.
Meets monthly on second Friday from October to May, at Wayne County Medical Society Building.

CENTRAL ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. H. C. Kariher, Decatur, Illinois.
Regular meetings held quarterly.

INDIANA ROENTGEN SOCIETY
Secretary, Dr. Carl S. Oakman, Muncie, Indiana.
Annual meeting each February 22 in Indianapolis. Next meeting in Indianapolis, February, 1929.

NEW ENGLAND ROENTGEN RAY SOCIETY
Secretary, Dr. M. C. Sosman, Peter Bent Brigham Hospital, Boston, Mass.
Meets monthly on third Friday, Boston Medical Library.

NEW YORK ROENTGEN SOCIETY
Secretary, Dr. E. Everett Rowell, 200 West 59th St.
Meets monthly on third Monday, New York Academy of Medicine.

CENTRAL NEW YORK ROENTGEN RAY SOCIETY
Secretary, Dr. D. S. Childs, 316 Gurney Bldg., Syracuse, N. Y. Three meetings a year—April, August and November.

PACIFIC COAST ROENTGEN RAY SOCIETY
Secretary, Dr. Harold B. Thompson, Seattle, Wash.
Two meetings a year.

ROENTGEN RAY SOCIETY OF CENTRAL PENNSYLVANIA
Secretary, Dr. W. E. Reiley, Clearfield, Penna.
Two meetings a year, April and October.

PHILADELPHIA ROENTGEN RAY SOCIETY
Secretary, Dr. John T. Farrell, Jr., 235 S. 15th St., Philadelphia.
Meets monthly on first Thursday evening, Pennsylvania Hospital.

ROCHESTER ROENTGEN RAY SOCIETY, ROCHESTER, N. Y.
Secretary, Dr. James M. Flynn, 282 Alexander St.
Meets monthly on the first Friday evening at 7.45 at the Rochester Medical Association Building.

ST. LOUIS ROENTGEN CLUB
Secretary-Treasurer, Dr. L. R. Sante, Metropolitan Building.
Meets first week of each month. Time and place of meetings designated by president.

TEXAS RADIOLOGICAL SOCIETY
Secretary-Treasurer, Dr. C. P. Harris, Houston, Texas.
Meets annually one day preceding the meeting of the Texas State Medical Association.

VIRGINIA ROENTGEN RAY CLUB
Secretary, Dr. Wright Clarkson, 205 S. Sycamore St., Petersburg, Va.
Annual meeting, Charlottesville, Va., Oct. 18, 1929

BRITISH EMPIRE

BRITISH INSTITUTE OF RADIOLOGY INCORPORATED WITH THE RÖNTGEN SOCIETY
Director, Dr. John Muir, 32 Welbeck St., London, W. 1.
Meets on the third Thursday of each month, from November to June inclusive, at 8.15 P.M., at 32 Welbeck St., London, W. 1., or as advertised.

ELECTRO-THERAPEUTIC SECTION OF THE ROYAL SOCIETY OF MEDICINE (CONFINED TO MEDICAL MEMBERS)
Meets on the third Friday of each month during the winter at 8. 30 P.M. at the Royal Society of Medicine, 1 Wimpole St., London, W. 1.

* Secretaries of societies not here listed are requested to send the necessary information to the editor.

RADIOLOGICAL SECTION, AUSTRALASIAN MEDICAL CONGRESS
Secretary, Dr. C. A. Anderson, The Hospital, Dunedin.

RADIOLOGICAL SECTION OF THE VICTORIAN BRANCH OF THE BRITISH MEDICAL ASSOCIATION
Secretary, Dr. Colin Macdonald, Lister House, 61 Collins St., Melbourne, Australia.
Meets monthly at Melbourne during the winter.

SECTION ON RADIOLOGY, CANADIAN MEDICAL ASSOCIATION
Secretary, Dr. A. H. Rolph, 160 St. George St., Toronto, Ont.

RADIOLOGICAL SECTION, NEW ZEALAND BRITISH MEDICAL ASSOCIATION
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch.
Meets annually.

CONTINENTAL EUROPE

BELGIAN SOCIETY OF ROENTGENOLOGY
Secretary, Dr. J. Boine, Avenue des Alliés, 134, Louvain (Belgium).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

SOCIETE DE RADIOLOGIE MÉDICALE DE FRANCE
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

SOCIETE FRANCAISE D'ELECTROTHÉRAPIE ET DE RADIOLOGIE MÉDICALE
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

ASSOCIATION OF GERMAN ROENTGENOLOGISTS AND RADIOLOGISTS IN CZECHOSLOVAKIA
Secretary, Dr. Walter Altschul, German University, Prague, 11/52.

DEUTSCHE RÖNTGEN-GESELLSCHAFT (GESELLSCHAFT FÜR RÖNTGENKUNDE UND STRAHLENFORSCHUNG)
Meets annually in April, alternating one year in Berlin, one year in some other German city. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
Permanent secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

SUD- UND WESTDEUTSCHE RÖNTGENGESELLSCHAFT
Meets annually in different cities.

NORD- UND OSTDEUTSCHE RÖNTGENGESELLSCHAFT
Meets annually in different cities.

DUTCH SOCIETY OF ELECTROLOGY AND ROENTGENOLOGY
Holds two meetings a year in Amsterdam, one in the Spring, and one in the Fall.

SOCIETA ITALIANA RADIOLOGIA MEDICA
Secretary, Professor M. Ponzio, University of Turin, Turin.

ALL-RUSSIAN ROENTGEN RAY ASSOCIATION, LENINGRAD, USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson.
Meets annually.
Sixth Annual Meeting, 1929, to be announced.

LENINGRAD ROENTGEN RAY SOCIETY
Secretaries, Drs. S. G. Simonson and G. A. Gusterin.
Meets monthly on the first Monday at 8 o'clock in the State Institute of Roentgenology and Radiology, Leningrad.

MOSCOW ROENTGEN RAY SOCIETY
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. A. Elektorowicz, 19 Hoza St., Warsaw.
Meets annually.

WARSAW SECTION, POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summertime.

SCANDINAVIAN ROENTGEN SOCIETIES
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with the exception of the Denmark Society, meets every second month except in the summertime:

SOCIETY OF MEDICAL RADIOLOGY OF SWEDEN
Meets in Stockholm.

SOCIETY OF MEDICAL RADIOLOGY IN NORWAY
Meets in Oslo.

SOCIETY OF MEDICAL RADIOLOGY IN DENMARK
Secretary, Dr. H. Scheuermann, Copenhagen
Meets on the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

SOCIETY OF MEDICAL RADIOLOGY IN FINLAND
Meets in Helsingfors.

VIENNA SOCIETY OF ROENTGENOLOGY
Secretary, Professor Holzknecht, Vienna, IX, General Hospital.
Meets on the first Tuesday of each month from October to July.

GRANTS IN SUPPORT OF RESEARCH ON THE EFFECTS OF RADIATIONS UPON ORGANISMS

At the meeting of the Division of Biology and Agriculture of the National Research Council, held in April, 1928, a group of investigators[1] requested approval by this division of an attempt to obtain funds in support of studies on the "Effects of Radiations upon Organisms."

This project was endorsed by the division and a general committee and a subcommittee on solicitation of funds were

[1] These individuals were: Edgar Altenburg, H. J. Bagg, A. F. Blakeslee, W. C. Curtis, A. U. Desjardins, C. Stuart Gager, T. H. Goodspeed, Robert F. Hance, F. B. Hanson, E. E. Just, Henry Laurens, C. C. Little, J. W. Mavor, H. J. Muller, Charles Packard, W. J. Robins, Herman Schneider, George Sperti, L. J. Stadler, Alexander Weinstein, P. H. Whiting.

immediately appointed, and, later, a subcommittee on allotment of grants.[1]

Generous response has been met in the early solicitations and the committee is able to announce that two contributions of $12,500 each have been received from the Commonwealth Fund and from the General Education Board. These contributions will be repeated annually for a period of five years, if satisfactory progress can be made in the support of these investigations. Contributions of other funds have been received from manufacturers and also of apparatus, such as roentgen-ray and ultraviolet equipment, and of the loan of radium, totaling in value about $40,000. It is expected that additional donations will be received. These contributions from manufacturers will be listed in a later announcement by the committee.

As these funds are now available, investigators, who have worked in this field or who have peculiar qualifications for such research, are invited to present requests for support not later than March 1, 1929, for the period ending May 31, 1930. Application blanks may be obtained about February 1.

The general conditions under which grants of money or apparatus will be made were stated as follows in the proposal approved in April, 1928, by the Research Council:

I. To be eligible for consideration, an investigator must present evidence, either in the form of published papers or otherwise, that he has a problem well in hand or he must have obvious qualifications to undertake such research. He must also satisfy the committee that his institution is furnishing reasonable support and equipment for general purposes if not the special features of this work. Time available for the research will be a consideration, particularly in the case of individuals engaged in teaching.

II. The items for which a grant may be expended will include:

(a) Salaries of research assistants, technicians, clerical assistants, and others who may be employed in the prosecution of any such investigation.

(b) Purchase of materials, instruments, equipment, etc., such as might not be expected in a laboratory with good general equipment.

(c) Any other assistance, exclusive of the investigator's salary, which any project legitimately requires. Under this head a limited amount may be spent for traveling expenses by the investigator.

(d) The investigator's salary will be paid in full by his institution, which will thus contribute by the time the individual is allowed for research as well as by the general facilities of a well-equipped laboratory. In some instances, however, it may be possible to allow men on sabbatical half-pay a balance on salary account, not to exceed $2,500 for a twelve-month period.

It is therefore intended that the institution in which the investigator is working shall do its share. The committee hopes to encourage research in smaller institutions and departments, as well as to support work in the largest and best equipped universities and research institutes.

More explicit statement of policy can not be made at the present time. All communications should be addressed to the Division of Biology and Agriculture, National Research Council, B and 21 Streets, Washington, D. C.

W. C. CURTIS, Chairman.
General Committee on Radiation.

[1] The personnel of these committees includes: *General Committee*, W. C. Curtis (Chairman), L. L. Woodruff, and D. H. Tennent; *Sub-committee on Solicitation of Funds*, W. C. Curtis (Chairman), C. C. Little, Herman Schneider, William Crocker, and L. L. Woodruff; *Subcommittee on Allotment of Grants*, D. H. Tennent (Chairman), G. H. Parker, H. S. Jennings, C. E. Allen, W. C. Curtis.

Vol. XXI, No. 1

DEPARTMENT OF TECHNIQUE

Department Editor: DAVID R. BOWEN, M.D., Pennsylvania Hospital, Philadelphia, Pa.

In this department will be published from time to time, as material is available, suggestions for improvement in technique.

AN EFFICIENT COMPACT ROENTGENOLOGICAL CHEST UNIT*

BY STAFFORD L. WARREN, M.D.

ROCHESTER, NEW YORK

IN these days of costly equipment and limited floor space, it is necessary to have a compact and efficient unit for examining chests. A suitable installation must be able to handle readily the roentgenoscopy of ambulatory and very ill bed patients and make it possible to take chest films under standardized conditions on all types of patients with a minimum of effort and time. The arrangement of equipment described below has been in constant use in this department for a year and a half and seems to meet all demands made upon it.

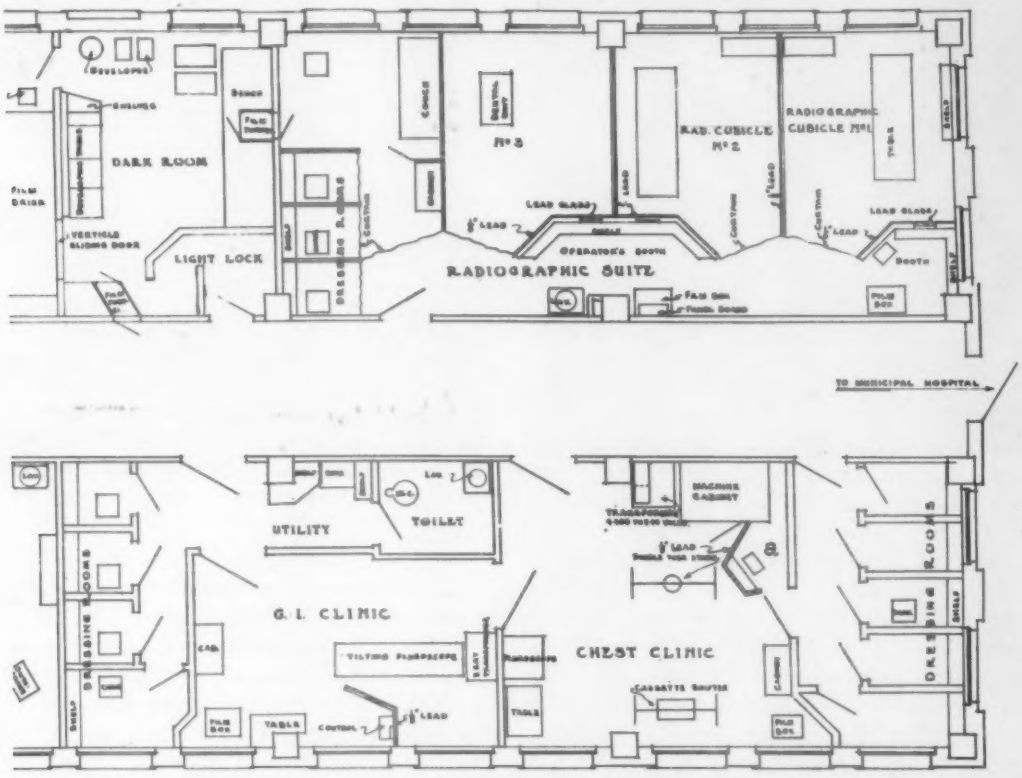

FIG. 1. Floor plan showing the arrangement of the equipment in the chest clinic to facilitate the maneuvering of bed cases, and the relationship of the chest clinic to the dressing rooms, etc.; (a) operator's cubicle.

The hall door (see plan, Fig. 1) is wide enough to admit the standard hospital beds on castors. A vertical roentgenoscope is placed almost in the right hand corner of the room in such a position that a bed can be pushed up to it under the roentgenoscopic screen. Bed patients, able to sit up in bed, can lean against the roentgeno-

* From the Department of Radiology of the Strong Memorial Hospital and the University of Rochester, School of Medicine and Dentistry, Rochester, N. Y.

scope, and a quite satisfactory roentgenoscopic examination can be made. Ambulatory patients are examined in the ordinary way.

A self-rectified, 5 in., 30 ma. unit is used to operate this roentgenoscope independent

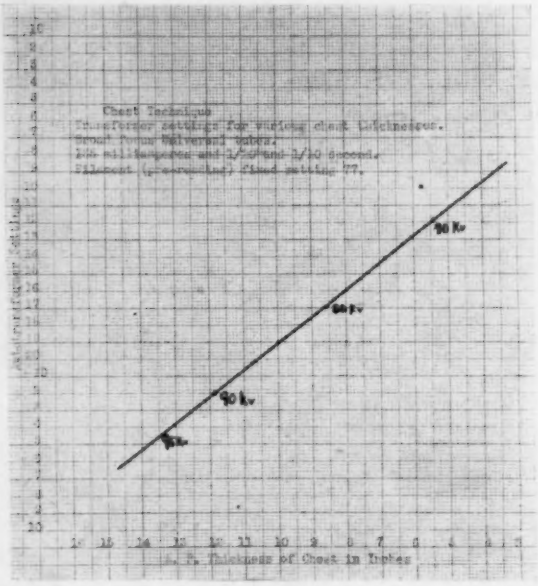

FIG. 2. Chart used to vary the voltage in accordance with the chest thickness.

of the roentgenographic machine. This simplifies the procedure considerably and avoids the danger of throwing heavy currents through the tube by mistake.

In the middle of the room, opposite to and at a distance of about 6 feet from the roentgenoscope, the motor-driven, stereocassette shifter is placed. This space is just about the minimum for maneuvering a bed. The cassette shifter is so placed that a bed can be brought up against it. Patients, able to sit up, can be placed against it without trouble, and films can be taken using a double tube stand which will be described in detail later.

If the patient is too ill to sit up, the bed is brought directly under a tube on the ceiling and films made as described below.

The operator's cubicle, as can be seen in Figure 1, is so placed that the patient can be seen at all times through a lead glass window. The cubicle has sufficient protection (¼ inch lead) and space for four people (standing) so that all of the attendants are safe-guarded. The sphere gap and high tension filament ammeter are in full view. Ambulatory cases enter from the dressing rooms through a door close to the operator's cubicle. The number of steps from the roentgenoscope to the cassette shifter and

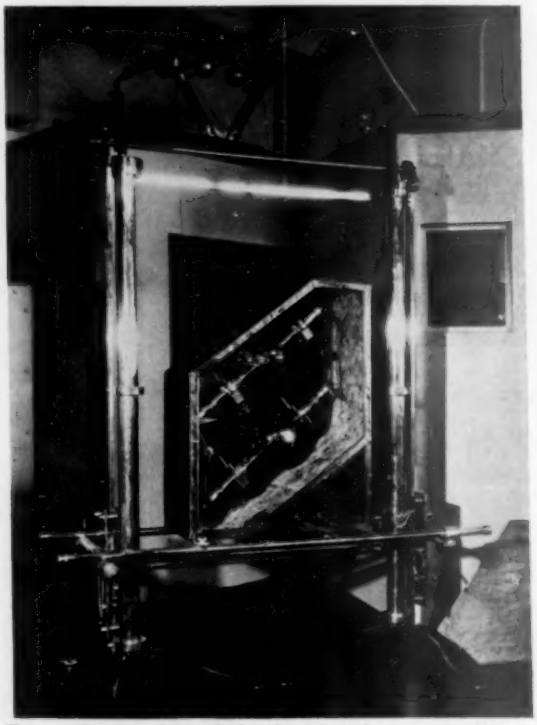

FIG. 3. Front view of the double tube stand with the front cover removed, showing the tube mountings, spacing, insulators and wiring.

from there to the operator's booth have been reduced to a minimum. The patients, when ready, can be ushered in and out without delay. Bed cases cause little disturbance in the routine unless they are infectious. For safety these patients are examined at the end of the clinic. Cases "on precautions" (diphtheria, pneumonia, typhoid fever, poliomyelitis, etc.) usually are not roentgenoscoped. A film tunnel is placed in a cloth cover and slipped under the patient's thorax, and films are taken with the overhead "ceiling" tube. All linen, gowns, etc., used are returned with the patient to the division. The patient is handled entirely by the nurse or attendant from the division so that the operator and equipment do not become contaminated. With this arrangement, many more ill patients can

be examined and the use of the mobile unit on the divisions is lessened, saving time and labor and facilitating diagnosis.

About 10 to 12 patients, irrespective of type, can be examined (roentgenoscoped and films made) per hour by one doctor with one technical assistant (maid) to handle the cassettes and move the patients. This could be speeded up considerably on ambulatory patients alone.

The voltage impressed upon the tubes is varied in accordance with the chest thickness. Each patient is measured and the autotransformer setting (previously calibrated for voltage reading by the sphere gap) read directly off from a chart posted in the operator's cubicle (Fig. 2) (Sampson[2]). For adults, the exposure time ($\frac{1}{10}$ sec.) and the milliamperage (130 ma.) are not varied ordinarily. For children, the time is reduced to $\frac{1}{20}$ of a second, and for oblique and lateral views of the chest, $\frac{1}{4}$ to $\frac{1}{2}$ second is used. The timer is a stock synchronous motor clutch type. On repeated checking with a spinning top and the electroscope, it has remained constant in the number of 60 cycle pulses which it allows to come through at all settings.

For the exposure of the films, the operator has two push buttons. One activates the cassette shifter and the tube filament shifter; the other, the timer. If stereos alone were taken, all three could be operated from one push button by inserting a relay in the cassette and filament shifter mechanism with a lag of the required period necessary for exposing the chest films. As stereographic films are not made as a usual thing, and as many oblique and lateral views are taken, it is essential that the two be separate. Single chest films are taken as a routine, stereoscopic films being made only for special study of some particular lesion or for the localization of a foreign body, abscess, etc.

Heart tracings are made with red and black grease pencils directly upon glass plates placed upon the roentgenoscopic screen. These are transferred to paper later and are used for special study only. Using the common standard distance of 6 feet for all of our chest films, heart measurements can be made from all chest films taken in this clinic. Thus, in cases developing heart disease at some later date, the previous films can be used for comparison of measurements. In measuring the heart, allowance can be made for systole or diastole by inspection of the

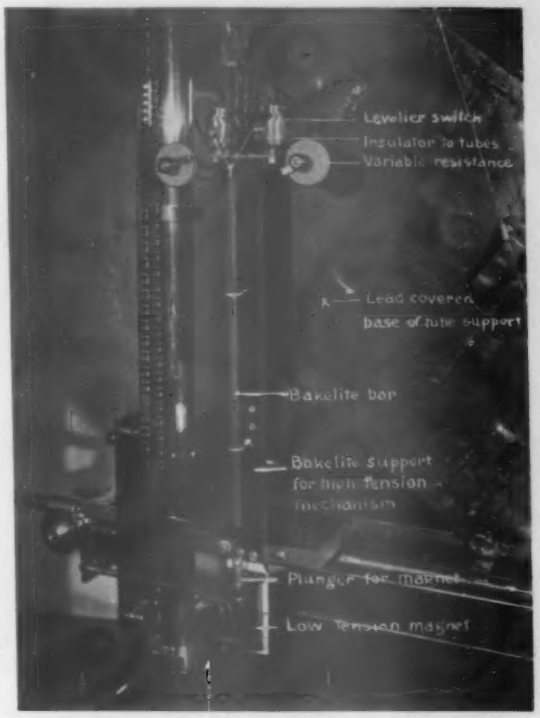

FIG. 4. Close-up of filament current shifting device; showing the two levolier switches, the variable resistances, the bakelite rod between the magnet and the pull chains of the switches. This whole mechanism is mounted upon bakelite supports.

film though the difference is only about 1 cm. in the total transverse diameter.

With short exposures ($\frac{1}{20}$–$\frac{1}{10}$ sec.), lung detail is particularly clear and sharp even in the bases and around the heart. The films will allow the use of a magnifying glass for closer study. Heart outlines are exceedingly sharp and clear cut.

THE DOUBLE TUBE STAND

In taking stereoscopic chest films at a distance of 6 feet, the proper shift for the target is 12 inches. To accomplish this with a single tube would require a complicated mechanism to avoid vibration, especially if any speed of shift were required. We have met this situation by mounting two tubes, one above the other, in a

lead box (Fig. 3) and shifting the filament circuit of the tubes (in the high tension) to take stereos. This shift is accomplished very simply by means of two pull-chain, levolier switches in the filament circuit (Fig. 4). The Coolidge tube filament circuits are connected in parallel with a switch in each filament circuit. The pull-chains are tied together and are pulled by a magnet (Fig. 4). With one levolier switch on and one off, a pull on their chains by the magnet will reverse the filament current. With the film cassette shifter motor or magnet in series with the magnet shifting the filament current from one tube to the other, one push button can control both the tube and cassette shift simultaneously. The magnet shifting the tube filament current is attached (for insulation purposes) to the pull chains of the switches by a bakelite rod 18 inches in length (Fig. 4).

As no two Coolidge tubes are apt to have exactly the same filament resistance, a variable resistance is mounted with each levolier switch in each filament circuit. These can be adjusted so that both tubes will take the same milliamperage at any kilovoltage (Figs. 4 and 5).

It can be seen that the high tension is on both tubes at the same time, but unless the filament is lighted, no current will flow nor roentgen rays be produced. As the targets are 12 inches apart and the tubes placed at almost 45 degrees to the horizontal for economy in spacing, there is plenty of room between the tubes to prevent sparking over. The box is partly lined with sheet mica wherever there is danger of this occurring (Fig. 3).

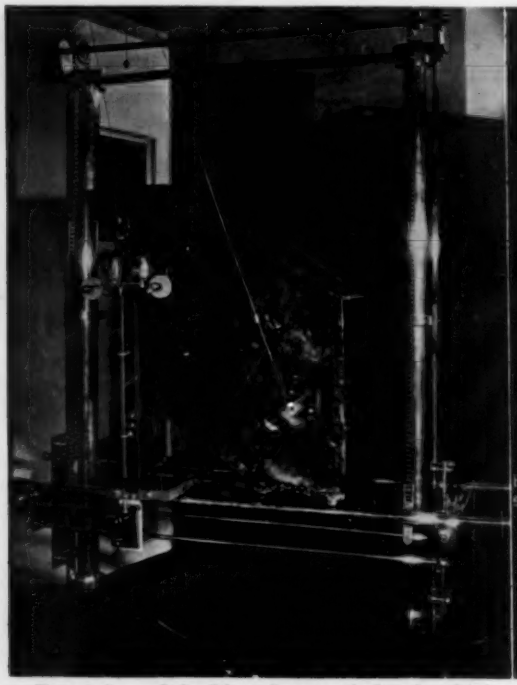

FIG. 5. Rear view of double tube stand showing high tension leads to insulators through the lead tube box; the filament current shifting device, the bearings for changing the position of the tube box either vertically or horizontally.

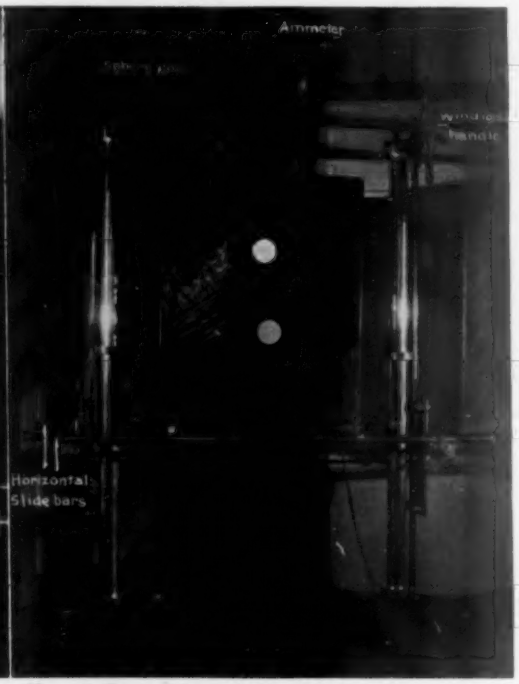

FIG. 6. Front view of the double tube stand with the lead front in place, showing the two 3 inch apertures covered with 1 mm. aluminum filter. Small holes are placed in each filter so as to throw a spot of light upon the patient for centering the target.

The lead box holding the tubes is mounted on a double tube stand. It is counterbalanced and arranged to be raised and lowered and also shifted on roller bearings from side to side. The tube stand is mounted on six castors and can be readily moved to change the film-target distance as desired (Figs. 6 and 7).

To center the target on the film in both tube holders (Fig. 6) a small hole ($\frac{1}{32}''$)

is drilled in the 1 mm. aluminum filter at such a position that the filament light reflected from the target throws a small round beam of light upon the cassette holder or the patient. This shows up readily in the dimly lighted roentgeno-

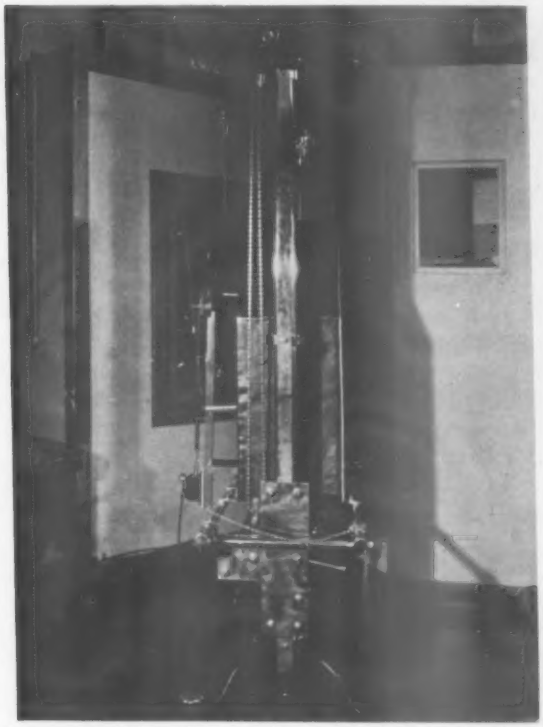

Fig. 7. End elevation showing counterbalance bearings, end plate, mountings, etc. The mounting of the filament circuit shifting device stands well out from the back of the tube stand to avoid spark-over.

scopic room and saves a lot of measuring and guessing and enables us to adjust the tubes and patient quickly and accurately to the proper position.

With the double tube stand, stereoscopic films can be taken slightly less than ¼ second apart. This period is limited by the time it takes the filament to heat up and the recently lighted filament to cool off. Both take about the same time. Films taken this close together have so far been equal in density and free from motion. Ideally, the films should be taken at a definite part of the heart cycle as described by McPhedran and Weyl,[1] and this speed of shift would readily accommodate itself to such a mechanism.

CEILING TUBE

The double tube stand can be used for all patients who can stand or sit up, but for those who must remain flat in bed, an overhead ceiling tube carriage is used (Fig. 8). This is nothing more than a lead

Fig. 8. Showing the overhead system and "ceiling tube" mounting. From left to right are the sphere gap, ammeter (filament), overhead switch, and tube carriage on rollers. The door stop at the lower right hand edge of the tube carriage stops the carriage at the end of the stereoscopic shift of 12 inches.

tube box mounted in a frame which runs on a cold rolled steel track. Heavy roller bearings allow the frame to glide quickly and smoothly the 12 inches necessary for the stereoscopic shift. An ordinary door stop brings it to a fixed position at the end of the shift without jarring the tube. The tube is mounted so that it is just 6 feet from the top of the mattress of a standard hospital bed when wheeled beneath it. Thus, a chest film can be taken at our standard distance on a very ill patient. By merely slipping a film cassette or cassette tunnel (for stereos) underneath the patient's thorax and adjusting the position of the bed, the procedure can be carried out with ease and little or no discomfort to the patient. Patients in appliances or frames are easily handled with the overhead tube.

In order to supply the other roentgenographic machines in the department as well as the chest machine with a stable line which would allow over 100 amperes at 220 volts to be drawn off without causing an appreciable voltage drop, a fortunate arrangement was possible. A high tension

power line of 4400 volts supplied the hospital transformers. It was found to be cheaper to bring this line across a court and up to the third floor, a distance of 500 feet, in subsoil pipes and 3 inch cast iron pipes than it would be to bring a line large

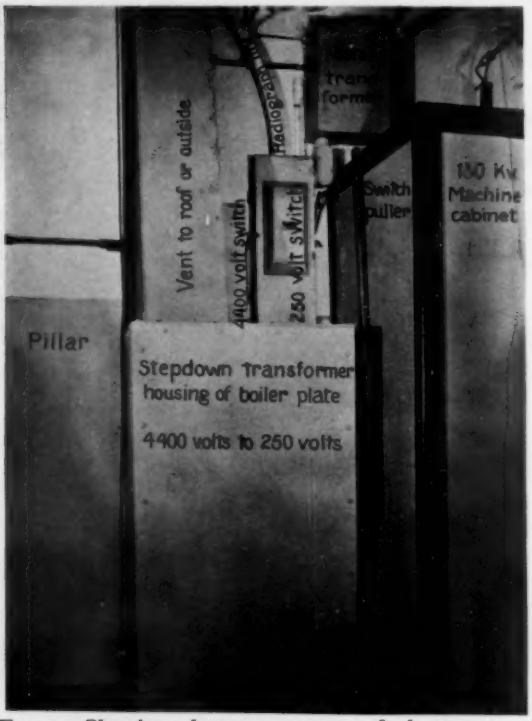

FIG. 9. Showing the arrangement of the vent and switches for the high tension step-down transformer. Note the short line necessary to supply the 150 kv. machine for high speed chest work. The roentgenographic line supplies the other roentgen machines.

enough to carry the same amount of power at 220 volts the same distance without current or voltage losses. This high tension, lead covered, duplex cable was brought into the corner of the chest room where it feeds a step-down transformer which otherwise would have been in the basement transformer room. This transformer is encased by boiler plate (Fig. 9) and vented to the outside by a special flue of boiler plate. A drain in the floor leads to a sink on the floor below. Thus, if the transformer should short circuit, boiling or burning transformer oil would not come into the room. An encased high tension switch (Fig. 9) is operated by a hook so that the step-down transformer can be shut off at night. There is so little noise or hum from this transformer that it is necessary, to put a pilot light in the hall to make certain that the switch is shut off at night. This arrangement made possible a short, heavy line to the transformer of the chest roentgenographic machine. With the use of large currents for a very short time, it is vital that there be no lag and voltage loss at least of a variable amount. Whatever lag and loss there is in the arrangement described here has been inappreciable and a constant. This has remained so on repeated calibrations for a year and a half.

CALIBRATION

The ceiling tube and the two tubes in the double tube stand (with their variable resistances) are adjusted to the same resistance so that the time, distance, milliamperage and kilovoltage factors are practically identical (actually about 5–10 per cent difference).

The machine (rated at 150 kv. and 500 ma.) is calibrated for kilovoltage with a sphere gap which has been checked with a spectrograph. The milliamperage is calibrated against a prereading filament meter and an ammeter in the filament (high tension) circuit. A few checks daily have shown this to be constant. The timer (a synchronous motor type) has been checked with a spinning top and the electroscope and also found to be accurate over a long period. A slight variation in any one of our factors will show up immediately and can be checked with little difficulty.

The only variable in our technique is the commonly used change in kilovoltage with the varying chest thickness. This seems to work fairly well giving uniform films day after day. The factors, using broad focus, universal Coolidge tubes, are: target film distance, 6 feet; milliamperage, 130; kilovoltage from 70 to 100 for chests varying from 6 to 12 inches in thickness; exposure time from $\frac{1}{20}$ to $\frac{1}{10}$ second. Three-quarter and lateral views of the chest can be taken in $\frac{1}{4}$ to $\frac{1}{2}$ second. Spine films can be made in from $\frac{1}{2}$ to $\frac{3}{4}$ second (without the Bucky) for actual measurements with this distance. No benefit in sharper detail seems to be derived from the use of medium or fine

focus or 100 ma. tubes, and they are apt to burn out more quickly. Three broad focus tubes have been in use almost a year without change or much injury to the targets and have stood many thousand exposures for testing and use in a chest clinic averaging about 300 cases a month.

The ideas incorporated in this unit have been gathered from many sources and I wish to express my thanks to the various individuals who have contributed suggestions from time to time. Special thanks are due to Mr. J. Ebert who did the machine work on the double tube stand and to Mr. Bartlett who assembled the ceiling tube carriage. Mr. Rymer, the electrician, enabled us to establish the high tension transformer in the department by solving the difficulties in its installation.

REFERENCES

1. McPhedran, F. M., and Weyl, C. N. Automatic synchronization of roentgen-ray exposures. *Am. J. M. Sc.*, 1925, clxix, 510–516.
2. Sampson, H. L. Roentgenographic chest technique. Am. J. Roentgenol. & Rad. Therapy, 1924, xi, 373–375.

BOOK REVIEWS

Books Received Are Acknowledged under Heading: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

DISEASES OF THE GALL BLADDER AND BILE DUCTS. A BOOK FOR PRACTITIONERS AND STUDENTS. By Evarts Ambrose Graham, A.B., M.D., Professor of Surgery, Washington University School of Medicine; Warren Henry Cole, B.S., M.D., Instructor in Surgery, Washington University School of Medicine; Glover H. Copher, A.B., M.D., Assistant Professor of Surgery, Washington University School of Medicine, and Sherwood Moore, M.D., Professor of Radiology, Washington University School of Medicine. Cloth. Price, $8.00. Pp. 456, with 224 illustrations. Philadelphia: Lea & Febiger, 1928.

The following subjects are covered in a thorough manner with abundant experimental evidence to substantiate each point: Anatomy of the Extra-Hepatic Bile Passages; Physiology of the Gall Bladder; Pathology of Cholecystitis; Gall Stones, Symptoms and Clinical Diagnosis of Diseases of the Gall Bladder; The Bile Ducts; The Radiology of the Biliary Tract; Application of Tests of Hepatic Function to Diagnosis of Biliary Disease and Surgical Treatment of Cholecystitis.

Where the mechanism is not definitely established all views and theories are advanced with experimental data both pro and con. This enables the individual reader to review the doubtful points so that each may be weighed according to its merits.

The chapter on radiology of the gall-bladder represents a résumé of all known work along that line. It commences with a historical sketch and goes through the rationale of cholecystographic interpretation along with the interpretation of cholecystograms in abnormal conditions and the diagnostic efficiency of the method. Both the intravenous and oral methods of administration of the dye are discussed in detail in an unbiased manner. The authors prefer the intravenous method since their experience leads them to believe that this is the most accurate. They, however, quote freely from those supporting the oral route so that each reader may draw his own conclusions. Each chapter is taken up in an equally thorough and efficient manner.

This book represents a vast amount of original work coupled with an extensive review of the literature on the subject both in this country and abroad. A complete bibliography is furnished and where the material is not the authors' own work the original reference is given so that if more detailed information is desired the articles may be easily obtained.

This volume is recommended as a complete and authoritative treatment of the biliary system and would be a worthy addition to any medical library either as a text or reference book. EDGAR M. MCPEAK.

HANDBUCH DER GESAMTEN STRAHLENHEILKUNDE, BIOLOGIE, PATHOLOGIE UND THERAPIE. VOL. I (first and second part). Edited by Prof. Dr. Paul Lazarus. Pp. 558, with 98 illustrations. München: J. F. Bergmann, 1927.

These are the first two parts of a handbook of the entire subject of radiotherapy which is published, as the editor relates in the preface, for the benefit of the practicing physician, the investigator, and the teacher of medicine.

The introductory chapter, written by P. Lazarus, intends to give a résumé of "new ways, of the nature, and of the indications in radiotherapy." It is concluded by the answers of Einstein to four fundamental questions regarding the physics of radiation. They cover the absorption of radiation, the specific effect of different wave lengths, the time factor in the application of radiant energy, and the sensitization of tissue in order to increase secondary radiation. A. Sommerfeld offers then, a brief but precise chapter on atoms, electrons, ions, and radiant energy, followed by C. Dorno's well-presented contribution on the physical foundations of sun and artificial light therapy. In a concise article, O. Hahn discusses the essential physical facts of the radioactive substances used in therapy.

The second issue is opened by Stefan Meyer who describes in a remarkably small space, the measuring methods of radioactive substances. Nevertheless, he handles his subject very efficiently, and although it brings in a good deal of physics, it is quite palatable for the physician who, as a rule, does not take kindly to that branch of science. The chapter on roentgen tubes and apparatus (R. Glocker) and principles of dosimetry (H. Behnken) are of equally high quality. The investigations of Dessauer and his coworkers concerning the distribution

of roentgen energy in water and also the so-called "heat point theory" which offers an explanation of the effect of radiation in tissues are described in detail (F. Dessauer and B. Rajewsky). The study of the last two chapters on the histopathology of radiation should prove interesting and profitable for every physician. They are written by well-known scientists who can speak with authority on the subject: Cl. Regaud and A. Lacassagne (Paris) and O. Lubarsch and J. Waetgen (Berlin). A more liberal use of illustrations would bring the last two mentioned essays close to perfection.

If one may judge from the material published so far and also from the list of contributors whose articles are to follow, this handbook can be heartily recommended as a valuable addition to the library of the radiologist.

E. A. Pohle.

INTERNATIONAL ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

BELOT, J., LEPENNETIER, F., and PELLIZZA, J. Diagnosis of some bone changes in the elbow. *J. de radiol. et d'électrol.*, Oct., 1928, xii, 457–500.

Lesions, particularly trauma, of the elbow are very frequent in the child and adolescent and the complexity of the joint makes clinical examination difficult. This makes roentgen examination of this joint particularly necessary on the first symptoms of any lesion. The health of the patient, or at least the function of the joint may depend on an early diagnosis. Roentgenoscopy is not sufficient; it requires a roentgen picture to show the finer details of the lesions. The picture may be taken with the arm and forearm completely extended with the olecranon resting on the film (anteroposterior view), with the arm and forearm completely extended, the anterior surface of the elbow resting on the film, with the forearm in semiflexion on the arm, the epitrochlea or epicondyle in contact with the film or with the forearm flexed on the arm and the dorsal surface of the olecranon resting on the film. The anteroposterior and profile views are particularly important and the technique of taking them is described in detail. Diagrammatic sketches of the development of the centers of ossification of the bones of the elbow are given together with a series of roentgenograms of the various forms of fracture of the elbow and the different forms of luxation, arthritis, tumors and congenital lesions of the elbow.

CLEVELAND, MATHER. Chondrodysplasia. *Surg., Gynec. & Obst.*, 1928, xlvii, 338–345.

A report is given of a case recently observed at the New York Orthopedic Dispensary in a boy treated since July, 1920, when he was two years of age. The deformity of the left leg was first noted at the age of six months, this being the only abnormality noticeable. The left tibia showed marked lateral bowing with the foot in varus deformity. The right foot was in valgus. The roentgenogram showed the distal inch of the tibia enlarged with a deficiency of bone structure apparently cartilaginous for the most part. The bone was of coarse structure and appeared in irregular strands and masses, extending from the bony shaft into the cartilaginous portion. The ossification was best developed posterior to the central axis of the mass and was absent at the periphery except for a flaring of the cortex of the shaft at the proximal end of the mass. There was no evidence of active destruction or effusion or infiltration. No opinion was recorded regarding diagnosis and no treatment suggested at that time.

At the age of six years, the left leg was almost 6 inches shorter than the right, shortening being distributed equally between thigh and leg, with sharp lateral bowing of both tibia and fibula. The report on the second roentgenogram read: "The same non-ossified and irregularly ossified areas are present, but there are a few dense calcareous nodules in the cartilaginous areas of the lesions." The Wassermann reaction was a doubtful positive and tests made on both parents were negative, but the patient was given four injections of salvarsan on the supposition that antiluetic treatment might help. Following these treatments an uneventful year intervened. Then an osteotomy of the tibia was done to correct the deformity. Two years later an exploratory incision was made for the purpose of microscopic examination of the tissue. From the pathological report a diagnosis of cystic degeneration of the cartilage was made.

This case is unquestionably a chondrodysplasia of the type called Ollier's disease, an asymmetrical cartilaginous dystrophy with resulting skeletal deformity confined to the left leg. It is undergoing delayed ossification and healing spontaneously. The affected long bones are growing. The disease is extremely disabling because of the unilateral retardation of bone growth.

EUSTERMAN, GEORGE B. A clinical appraisal of cholecystography. *Surg., Gynec. & Obst.*, 1928, xlvii, 567–568.

Cholecystography is undoubtedly the best existing single laboratory test and promises to be as extensively utilized in the diagnosis of cholecystic disease as roentgenoscopy in diseases of the upper digestive tract. It is also an indispensable method in studying the function of the gall-bladder. The physician and surgeon should, however, be cognizant of certain definite limitations to the method. Diagnostic accuracy as high as 98 per cent has been claimed. The actual diagnostic value of the method can be determined only by a considera-

tion of its limitations and possibilities for error. To do this it is necessary to adopt a common standard of what constitutes sufficient gross and microscopic evidence of cholecystic disease. Positive evidence of disease in the cholecystogram has been found in cases showing definite clinical signs of cholecystic disease, chiefly calculous cholecystitis, hydrops, empyema, acute, subacute and gangrenous cholecystitis and obstruction of the cystic duct.

In another group of cases the clinical history and physical examination after exclusion of the stomach and duodenum as the site of disease often enabled a diagnosis of definite cholecystic disease. In this group cholecystographic examination would have been superfluous except for scientific reasons. Finally, the high degree of cholecystographic accuracy in cases verified surgically was probably more apparent than real. Such cases were really sifted out by the clinician.

Positive errors in the method are especially obtained in two clinical types of cases: the asthenic, visceroptotic, nervous patient with gastric subacidity or anacidity often associated with a lowered basal metabolic rate, and the patient with hyperacidity from whatever cause, and especially one with duodenal ulcer. In a large series, 41 per cent of the proved positive errors occurred in patients with duodenal ulcer in whom the gall-bladder was found objectively normal at operation.

False negative diagnoses range as high as 25 to 30 per cent. This important feature seems not to have been sufficiently stressed. The silhouette of the thickened diseased gall-bladder itself may simulate the presence of the dye-filled viscus.

Cholecystography is essentially a test of function and not of disease. The identification of stones as shown by negative shadows is the chief exception. At the present stage of development, cholecystography should not be relied on to the exclusion of other data to affirm or reject the existence of a diseased gall-bladder.

Miller, Harold A., and Martinez, D. B. Iodinized oil in the diagnosis of pregnancy. *Radiology*, 1928, xi, 191–193.

The authors have used the injection of iodized oil for the early diagnosis of pregnancy in 15 cases, none of which gave signs of threatened abortion before the test. A positive diagnosis of pregnancy was made in every instance. With this small series the authors discontinued this procedure because 3 of the cases aborted—three, four and five days respectively after the injection. In consequence of this experience the authors believe the lipiodol and roentgen-ray examination to be dangerous and unjustified.

Before lipiodol injections are made the cervix must be healed, and if tubal trouble is suspected all active inflammation must have subsided for months or longer. The outlines of the uterine cavity and tubes are easily visualized by this method and this is of great aid in eliminating the closure of tubes as a cause of sterility. In the gravid uterus the lipiodol shows as an irregular mass filling that part of the uterus unoccupied by the fetus which bulges toward the center of the cavity giving a very clear picture of its point of attachment.

Murphy, John T. Intracranial calcifications. *Radiology*, 1928, xi, 213–216.

Intracranial calcifications are still sufficiently rare enough to be of interest and at times confusing. The most common shadow seen and recognized as of no pathological significance is the calcification which occurs in the pineal gland. It occurred in over 40 out of 100 successive cases. It is often of the size of a pea, situated about 3.5 cm. above the middle of the external auditory canal.

The next most common of these densities seen are in the calcifications in the falx cerebri. These may be of any size and occur in any part. They are of no clinical significance but may occur in the skull in which pathology is present.

Calcification of the walls of the blood vessels appearing as concentric rings may be found in many positions in the skull but most commonly in the region of the mid-brain. They may occur as small flecks of lime or relatively large masses. No clinical significance can be attached to these except that of the general condition of the patient's arteries. They may be calcified aneurysms, from which they cannot be differentiated. Bridges of new bone formation about the sella turcica are frequently seen in differing amounts.

In very old persons there may be a definite retraction of brain tissue, the inner plate of the skull may take up this space, the new bone conforming to the brain markings. This is a physiological process.

Ratti, A. Roentgen study of diverticula of the duodenum. *Radiol. med.*, Nov., 1928, xv, 1111–1121.

A case is described in a man of forty who had had symptoms for seven months that indicated ulcer of the duodenum. He was sent for roentgen examination which showed a diverticulum of the first portion of the duodenum. Recently cases have been described of extro-flexion of the

wall of the duodenum which originated from ulcers. When the bulb of the duodenum is deformed by scars from ulcers extroflexions of a diverticular type may be produced, sometimes solitary, not infrequently multiple. They are called paraulcerous diverticula; they are about the size of the last phalanx of the little finger and are generally hard to recognize on roentgen examination, as their picture is not very different from that of a niche. They are not really diverticula but deformities of the bulb brought about by the healing of ulcers. But the diverticulum in this case was not of this type; it was large, mobile and contractile. It was evidently a true diverticulum of congenital origin; at least there is a congenital predisposing cause in weakness of a part of the wall of the duodenum which when acted on by other exciting factors, such as spasm for example, produces diverticulum.

REINBERG, S. A., and MANDELSTAM, M. E. On the various types of dextrocardia and their diagnostics. *Radiology*, 1928, xi, 240–249.

Four types of dextrocardia should be distinguished: (1) Dextrocardia in situs viscerum inversus totalis, characterized by a reversed roentgen image and an inverse electrocardiogram in the I lead (rarely in the II lead as well); (2) isolated congenital dextrocardia with inversion of the heart cavities, characterized by a reversed position of the heart and the aorta but a normal position of the abdominal viscera and by an inversion of the electrocardiographic waves; (3) isolated congenital dextrocardia with a normal interrelation of cavities in which the heart is situated on the right, the aorta passes over the left bronchus, the abdominal viscera are normally placed, and the electrocardiogram is normal; (4) acquired dextrocardia which is characterized by the same peculiarities as type III and pathological changes of some of the adjoining organs.

Combined roentgenological and electrocardiographic examination is decisive for the differentiation of the various types of dextrocardia. The position of the diaphragmatic domes is due to the position of the heart and not the liver. That side of the diaphragm on which the heart rests is lower.

TARTAGLI, D. Congenital changes in the skeleton. *Radiol. med.*, Nov., 1928, xv, 1065–1068.

The patient, a child of five, was not able to walk because of the great difference in the length of his legs due to defective development of the right one. When he lay down the right leg was in abduction and external rotation with semiflexion of the distal part and valgus position of the foot. In horizontal decubitus all the right stump, including the foot, did not equal the length of the left femur. Roentgen examination showed complete sacralization of the last lumbar vertebra. The arches of the last two sacral segments showed incomplete fusion and there was therefore rachischisis. The left ilium was normally developed; the right one was racket-shaped. There was aplasia of the right femur with posterior luxation of the stump, absence of the fibula and deformity of the tibia, absence of the patella and some of the bones of the tarsus. The author thinks these congenital anomalies were probably due to a very tight amnion which exercised continuous pressure and so brought about the changes in the skeleton. If this was the cause it must have taken place about the 7th week of fetal life when the skeleton was in a cartilaginous condition.

TITTERINGTON, P. F. Fractures of the bones of the face. *Radiology*, 1928, xi, 207–212.

Consideration is given to fractures limited to the malar bone and its attachments and the zygomatic arch. The malar bone itself is rarely fractured; usually the break occurs at the attachments. The zygomatic arch is most frequently involved. The deformity in such fractures consists of a depression to the outer side of and below the eye. In demonstrating the fractures in the bones in the upper part of the face, a position practically the same as that employed by Waters in showing the antrum is used. In the first position the patient lies on the abdomen with the nose and chin resting upon the cassette supported by a 23° angle board. The central ray is directed downward so that it passes through the center of the malar bone. In demonstrating the bones of the lower part of the face, especially the zygomatic arch, the head is placed the same as in the first position; the tube is tilted 15° toward the feet and then moved toward the head of the table until the central ray passes through the midportion of the arch. A Potter-Bucky diaphragm is used, distance 32 in., 75 to 85 kv., 3½ to 5½ sec. exposure, through 1 mm. Al. The lower voltages and shorter exposures are used in the first position and the higher voltages and longer exposures in the second position. A series of 21 cases were studied. It was found that a certain percentage of fractures of the facial bones, especially those with only a slight displacement are easily overlooked. In cases examined shortly after injury, extravasation into the antrum is frequent—a condition which apparently clears up in a short time. Surgical interference is

indicated in those cases having a wide separation of fragments. In cases not operated on, union is slow or fails to take place. When the trauma is directly over the zygomatic arch, a triple fracture with depression usually results. The fractures are at the articulations and through the center of the bone, the depression being at the middle fracture. When the trauma is directly over the malar, the first fracture is at the articulation with the superior maxilla. The involvement of the other articulations of the malar and the extent of the fractures through these articulations are directly proportionate to the force of the blow.

Viviani, R. Significance of the gall-bladder imprint. *Radiol. med.*, Nov., 1928, xv, 1087–1110.

With the object of determining the significance of the imprint of the gall-bladder on the picture of the stomach and duodenum the author studied 50 normal subjects. The imprint was not constant in these subjects. In some cases he saw transitory shadows. But in subjects with digestive disturbance he saw constant and characteristic gall-bladder imprints. Three of these subjects had appendicitis and the gall-bladder was found normal on operation. Some of them had colitis, one had a duodenal ulcer. In the majority there was no organic disease but the digestive disturbances were functional. The author thinks there may sometimes be a functional imprint due to hypertonia of the gall-bladder as compared with the tonus of the stomach and duodenum. He describes in detail the characteristics of the imprint which he calls functional, saying that it is a sign of considerable value in diagnosis though its interpretation is often difficult.

ROENTGEN AND RADIUM THERAPY

den Hoed, D. Radiotherapy of cancer of the uterus. *Strahlentherapie*, 1927, xxvii, 426–441.

The author reports 13 mild cases, 61 moderately severe ones and 32 very severe ones. He found that inoperable carcinomas of the portio can be permanently cured in a certain percentage of cases if no distant metastases have yet developed and the tumors have not infiltrated the surrounding tissues too far. His experience has shown that the Dessauer method does not give as good results as irradiation with small fields. From experience during the past year, which seems to confirm reports in the literature, they expect better results from radium irradiation with large doses (4000–7000 mg. radium element, filtration with 1.5 mm. aluminum and 3 mm. lead), combined with not too strong roentgen irradiation than with either of the methods mentioned above. The results depend on voluntary interruption of the treatment by the patient as well as on the technique of irradiation so it is best to keep the patient in the hospital uninterruptedly during the treatment. After-irradiation is advisable in operated cancer of the cervix. Carcinoma of the body of the uterus should be operated on. If there are contraindications to operation or the tumor is inoperable roentgen and radium irradiation are capable of bringing about not only palliative results but even permanent cures.

Feldweg, P. An unusual case of injury of the fetus by roentgen rays. *Strahlentherapie*, 1927, xxvi, 799–801.

The patient was a very obese woman of thirty-six who was treated in October, 1926, for irregular periods, being given a castration treatment of about 160 r on each ovary. She did not know whether she had had her last period in September or October, 1926. She was so obese that the uterus could not be palpated: there were no signs of pregnancy. On Apr. 6, 1927, she reported that she thought she was pregnant. She had not had any period after the irradiation. The fundus of the uterus could be felt half a hand's breadth above the costal arch. Premature delivery was induced on the 11th and a girl 41 cm. long and weighing 1200 gm. was delivered. Calculating the age of the fetus according to Zangemeister's tables the irradiation must have been given in the 4th to 6th week of pregnancy. The child's forearms were luxated outward at the elbows and were abnormally movable. On the right hand in place of the thumb there was a structure the size of a cherry with a small pedicle with a trace of a nail but no bone. A roentgen picture showed the radius lacking on both sides. The child died in a few days with signs of inanition; no other abnormalities were discovered. The mother had had 6 normal children before and there was no history of abnormalities in the family.

Pregnancy should be definitely excluded before giving roentgen treatment. If in spite of all precautions a fetus is acted upon by the rays during its development abortion should be performed.

Frontz, William A. A consideration of bladder tumors with special regard to the therapeutic measures best suited to the different types. *Surg., Gynec. & Obst.*, 1928, xlvii, 413–416.

Much of the confusion in the past regarding

the most appropriate treatment to be applied to any given case of bladder tumor is the result of the present classification which is based upon the histological findings in fragments removed by cystoscopic means. It has been repeatedly demonstrated that there is great possibility of error in basing a diagnosis upon the histological study of a single specimen thus obtained. Insofar as the so-called papillomata are concerned, the differentiation between benign and malignant forms is of no practical import from the standpoint of therapy as both respond to a combination of radium and fulguration.

In case of the so-called papillary carcinoma, great confusion is present as the non-infiltrating tumor of this type may present a histological picture identical with the tissue obtained from the surface of a tumor, the base of which has extensively infiltrated the bladder wall. An early differentiation of these two types of tumor is most essential as the former usually responds to surface application of radium and the latter requires an extensive surgical procedure.

It is believed that much of the confusion created by the histological classification will be obviated by substituting for it one based upon the cystoscopic findings alone. Under this classification tumors would be designated as either non-infiltrating or infiltrating. The experienced cystoscopist will usually have little difficulty in making this differentiation. In borderline cases, however, the tumor should be regarded tentatively as non-infiltrating and treated accordingly. Experience has shown that practically all of the non-infiltrating tumors will respond to endovesical measures consisting of radium fulguration alone or in combination. In the infiltrating types these methods are contraindicated. All of the infiltrating tumors so situated as to permit resection should be treated even though transplantation of the ureter will be necessary. However, in other tumors which are too extensive or which involve the vesical orifice and the prostate, the implantation of radium is recommended.

FÜRST, WALTER. Therapeutic interruption of pregnancy by roentgen irradiation. *Strahlentherapie*, 1927, xxvii, 496–510.

Cases are reported in which roentgen rays were used for the production of therapeutic abortion. The patients were given irradiation on two abdominal and two back fields measuring 9 × 20 cm. with a surface dose of about 700 R and a deep dose of about 300 R; symmetry apparatus, Coolidge tube, 2 ma., tension about 180 kv., focus-skin distance 30 cm., filter 1.2 mm. copper and 1 mm. aluminum. The author always succeeded with this dose in killing the fetus, and on waiting long enough the fetus was delivered. The average time between irradiation and abortion is twenty to fifty-four days. But this long period between irradiation and spontaneous delivery of the fetus is not in itself sufficient to necessitate rejecting the method. But in addition to that there is sometimes retention of the placenta or parts of it. This opens up blood vessels through which bacteria from the vagina and vulva may enter the cavity of the uterus and infect the remnants of placenta. So roentgen abortion has the disadvantage of involving danger of hemorrhage and infection of the delayed abortion. With a very few exceptions, therefore, in which operation was contraindicated he would not use roentgen abortion. But it is always possible to kill the fetus in the uterus. It seems to be only a question of dosage. The indications for roentgen deep irradiation in gynecology should not be decided upon by a roentgenologist who is not a specialist in gynecology.

GÁL, FELIX. Late results of radiotherapy in carcinoma of the female genitalia. *Strahlentherapie*, 1927, xxvii, 27–53.

The author reports a total of 603 irradiated cases. Among them are 47 inoperable patients that are alive after more than five years. While this is a small number it is important in view of what these patients ordinarily suffer. Their lives have been lengthened and rendered much more endurable. The author has found that combined radium and roentgen treatment is to be preferred to radium treatment alone as fewer radium irradiations are required and there is less injury of the tissues. In postoperative prophylactic treatment roentgen rays are to be preferred to radium.

GAUSS, C. J. The treatment of choice in myomas and hemorrhagic metropathies. *Strahlentherapie*, 1927, xxvii, 5–26.

In women past child-bearing age irradiation is the treatment of choice unless there is uncertainty as to whether the tumor really is a myoma or a malignant tumor; in the latter case the conditions for later possible necessary operation might be made worse by irradiation. In young women, of course, menstruation and capacity for child-bearing should be preserved as far as possible. This was attempted before the era of irradiation by enucleation of the myoma and preservation of menstruating mucous membrane. But in spite of the good results reported there were serious objections to the so-called conservative methods of opera-

tion, including a mortality at least as high as that of radical operation, the possibility of recurrence after the operation and the fact that pregnancy rarely occurred after them. For these reasons many authors preferred radical to conservative operation. Of course irradiation has the advantage over any form of operation of being less dangerous. There is still a great deal of discussion as to whether there are disadvantages that overbalance this. The author believes the signs of the menopause are not any worse after irradiation than after operation and that they are less in young women than in those approaching the climacteric. If it really becomes possible to bring about temporary sterilization by irradiation and stop menstruation for a sufficient time without danger of permanent amenorrhea and injury of the fetus, the problem of the treatment of myomas and metropathies in young women would be settled. But that is a problem for the future.

Roentgen irradiation is better than radium irradiation in large myomas that reach above the umbilicus. Smaller myomas and metropathies may be treated by either method. Radium irradiation has the advantage of prompt hemostasis, apparently better action on the tumor and less sickness from the irradiation. Radium therapy is to be preferred if the chief feature of the clinical picture is anemia. The original method of series of irradiations has been given up practically entirely for a single intense irradiation.

Krause, Paul. Roentgen therapy of Basedow's disease. *Strahlentherapie*, 1927, xxvii, 393–412.

The literature of the subject since 1901 is reviewed, and the author thinks roentgen therapy of Basedow's disease is of almost equal value with operative treatment. Among 1,788 cases reported in the literature he used 1,342 cases from 31 reports which seemed to be reported with sufficient detail to be of value. Positive results were obtained in 17 to 100 per cent, on an average in 82 per cent, and a negative result on an average in 18 per cent. There was cure in 137, or 10 per cent of the cases while 6, or 5 per cent, grew worse. A large number of observers reported almost exactly 80 per cent results. Glasafeld reports 2,032 cases of Basedow's disease treated operatively with 82 per cent recoveries and 5.4 per cent mortality; the statistics collected by the author give 80 per cent good results in the roentgen treatment of the disease, only 2 per cent less than for surgical treatment.

From his own experience he recommends using roentgen treatment in acute and severe forms of Basedow's disease, in neurasthenic symptoms due to a basedoid condition which have become more frequent in Germany in the last decade than formerly, and in women with preclimacteric symptoms, particularly heart symptoms. In these latter cases roentgen treatment of the thyroid and when necessary of the ovaries also is better than organotherapy.

Lacharité, H. Radiotherapy of giant Cell tumors of bone; results and technique of the Radium Institute of Paris for the cases treated from 1919 to 1926. *J. de radiol. et d'électrol.*, Nov., 1928, xii, 521–535.

Case histories are given of 14 cases of giant cell tumors of bone treated during the period 1919–1926. Five of the patients were between six and fifteen years of age; 5 between sixteen and twenty-five and 4 were thirty-one, thirty-four and forty-six; 11 of them were female and only 3 male. Five were treated with radium and 9 with roentgen therapy. The radium was applied by radium puncture in 3 cases, by means of an apparatus molded to the surface to be treated associated with radium puncture in one and by radium associated with surgery in one. The dose varied from 5.58 to 18.86 mc. given in one or several applications over a period varying from four to ten days. The interval between the applications was six weeks to three months. The rays were filtered through 0.4 to 1 mm. platinum. When roentgen therapy was used almost the whole of the surface dose was applied to the tumor by the use of a long focus distance and of very penetrating filtered rays. The doses used varied from 50 to 80 Holzknecht units (12,500 to 20,000 R units) and they were applied over a period varying from fifteen to forty-five days.

All 14 of the patients were cured so radiotherapy is the treatment of choice in giant cell tumors of bone and promises complete cure and normal function without operation. In some very advanced cases there may be only arrest of the process without bone repair, but even in these cases the patients will be in much better condition for curettage than before the irradiation. Radiotherapy stops the growth of the tumor, causes a solid encapsulation followed by slow regression and ossification, and cures the objective and functional symptoms. It does not involve any danger as the doses required are relatively low. Postoperative recurrences also respond to irradiation but the reaction takes place later and they are more resistant than non-operated tumors. Prophylactic postoperative irradiations are not to be advised. They might pre-

vent recurrence but would retard bone repair. Radiotherapy is more effective when given in a short period of time.

LAHM, W. Radium irradiation of carcinomas of the cervix. *Strablentberapie*, 1927, xxvii, 442–486.

Detailed descriptions are given of the histological findings in a series of exploratory excisions in 24 cases of carcinoma of the cervix treated with radium with a view to determining the biological action of the rays. The process of degeneration in the carcinoma cells resulting from irradiation is quite different from that which takes place spontaneously. In the majority of cases histological examination shows that there has been a previous irradiation. Degeneration of the nucleus is the characteristic sign of irradiation. The cell nucleus is injured by the rays no matter whether it is undergoing mitosis or not. There is always a change of the nature of acid formation and agglutination or swelling; these may be due to decreased electrical tension or increase of albumin compounds poor in nitrogen. The injury of the carcinoma cells may vary in degree and so result in calcium incrustation of the chromatin, hypertrophy or destruction of the nucleoli or amitotic division of the nucleus, which is not followed by division of the protoplasm. If the carcinoma cell is acted on while undergoing karyokinesis it may result in pycnosis and agglutination of the chromatin loops. It is possible that there may be differences in sensitiveness between resting cells and ones undergoing mitosis but the author does not think it is proved. Doubtless the processes take place more rapidly in dividing cells, which has been taken for greater sensitiveness. If the action of the rays is slight, the mitosis of the nucleus is completed without division of the protoplasm, resulting in formation of giant cells with very small nuclei; if the action is stronger the chromatin substance is broken up and absorbed in the cell or set free by rupture of the cell. The terminal stage of these necrobiotic processes may be still further complicated by keratinization or mucous degeneration of the protoplasm. Changes take place in the fixed connective tissue cells and the white blood cells that are not unlike those just described. In many cases there was increased eosinophilia after the first irradiation. The author thinks this local eosinophilia is a vagotonic-anaphylactic phenomenon due to the reaction of a sensitized organism to a renewed supply of specific albumin. The absorption of cancer albumin has made the organism hypersensitive and the irradiation floods it again with cancer serum.

The disputed question of whether the rays exercise a stimulant or a degenerative action is answered by these examinations, as even the weakest irradiation with 156 to 216 mg. radium element causes changes in the carcinoma cells which are the first stages of lethal degeneration. It has been thought heretofore that absorption of the cancer tissue is brought about chiefly by phagocytosis but these examinations show that this is not true. Absorption is a process of lysis in the dissolved defensive substances of the blood or tissue fluids.

The cases do not give much information in regard to the relation between the size of the dose and the effectiveness of the irradiation. The dosage in all the author's cases was high but there was no severe local degeneration of the tissue. Such large doses would not have been required for local action on the carcinoma, but the object was to bring about a sufficient deep action of the rays. At present other methods are used for that, particularly combination with roentgen rays.

LOEB, L. FARMER, and WRESCHNER, MARIE. Effect of beta rays on carcinoma. *Strablentherapie*, 1927, xxvii, 487–495.

A uranium × preparation that emitted beta rays was used for the intramural treatment of malignant tumors. This results in a suspension of activated iron hydroxide particles in a solution isotonic with the body fluids. The particles are non-absorbable, remain at the site of injection and emit primary electron rays. Experiments were made on normal mice, rats and rabbits with this preparation, and it did not have any injurious effect. Experiments on rats with Flexner-Jobling carcinoma showed a distinctly good effect on the tumor in a large number of cases. Experiments made so far on human patients with cancer confirm the results of animal experiment.

MUHLMANN, E. Roentgen therapy associated with grape sugar injection. *Strablentherapie*, 1927, xxvii, 306–310.

E. G. Meyer reported at the Roentgen Congress in 1926 that his results with roentgen therapy had been improved by associating with it intravenous injections of grape sugar. The author tested the method in 22 cases, giving an intravenous injection before every irradiation whether with roentgen rays or radium. In the beginning he injected 3.3, later 4.5 grape sugar in 10 c.c. water. The technique of the irradiation was not changed. The course of the reaction was not affected, showing that the dextrose did not sensitize the cells, as has been claimed by some authors.

And there was no particular change in the course of the tumors except in 2 cases in which recovery appeared to be more rapid. One was a sarcoma of the portio and the other a carcinoma of the tonsil with many gland metastases in the neck. But such results are sometimes seen without dextrose. The course was very favorable in 6 other cases also, but not more so than it might have been with the roentgen rays or radium alone without the dextrose. But one rather striking effect of the dextrose treatment was that it prevented roentgen sickness. If any nausea or loss of appetite did occur it was quickly cured by another dextrose injection. But he did not observe any specific effect on the tumor at all and thinks perhaps the results described by Meyer and others were due to alleviation of roentgen sickness.

Murphy, Douglas P. Ovarian irradiation; its effect on the health of subsequent children. *Surg., Gynec. & Obst.*, 1928, xlvii, 201–215.

The literature bearing upon ovarian irradiation as it may affect the health of subsequent offspring in animals and in humans has been reviewed. Frequent serious developmental disturbances have been observed in animal and human offspring when the pregnant animal or human or the fertilized egg has been directly irradiated. The disturbances are severe in nature and in human beings present themselves most frequently in the form of arrested cerebral development characterized by the condition known as microcephaly. Abnormalities of development and of structure have been observed in the young of animals irradiated prior to conception or fertilization. Children born of women who have been irradiated in the pelvic region prior to conception also present abnormalities of development and disturbances of health, early death and other abnormal conditions. These abnormal conditions are not especially frequent nor are they uniform in character.

Concerning the effect upon the health of future children, of irradiation when applied in the ovarian region before pregnancy has taken place, no definite answer can be given. Results of animal experimentation indicate that damage to subsequent offspring is likely to result. This evidence is, however, not yet of sufficient weight to justify a final conclusion. The number of preconception radium and roentgen-ray treatments (approximately 265) recorded in the literature, with their associated births at the close of term, including only 10 cases in which the children born at that time were not normal, do not present any very striking indication that the previous maternal irradiation had any definite or serious effect upon the health of the children born following such treatments.

It is concluded on the basis of study that irradiation of pregnant animals or human beings is a procedure extremely dangerous to the health of the offspring (61.3 per cent defective) and in the case of human beings ought not to be undertaken unless such existing pregnancies are to be terminated artificially prior to the period of viability of the child. A classified bibliography of 155 references is appended.

Schreus, H. Is borderline ray therapy superior to the surface therapy previously used? *Strablentberapie*, 1927, xxvii, 511–517.

Comparative experiments in the therapeutic action of ¼–⅓ skin erythema dose of roentgen rays of moderate hardness and ⅔ to 3.5 erythema dose with borderline rays showed that the action of the borderline rays was always inferior. In many cases there was a long continued pigmentation of the skin that had a bad cosmetic effect. Measurements of absorption showed that the basal layer of the skin is not spared any more by therapeutically effective doses of borderline rays than by roentgen rays. The mechanism of action of the borderline rays seems to be the same as that of the roentgen rays.

Simon, Stefan. Rectal use of radium. *Strablentherapie*, 1927, xxvii, 70–80.

A rectal radium carrier is described and illustrated which should be used in all carcinoma cases in which a combined vagino-rectal or cervico-rectal application of radium is desirable. Rectal irradiation alone can be used in cases in which prophylactic irradiation is desirable following radical operation or for a curative or palliative action in recurrence. The advantages of this carrier are that it is simple; it is little trouble to the patient though it may have to be left in a long time; the parametria and region of the portio may be irradiated from several fields distributed over the whole of the rectum; it is adapted not only for cases of carcinoma of the portio or vagina but also for ones of the prostate and rectum.

Strassmann, Paul. The radiotherapy of myomas. *Strablentberapie*, 1927, xxvii, 281–296.

From 1918 to 1926 a total of 1,032 myoma patients have been treated at the author's clinic in Berlin. Among these 503 were irradiated and 529 operated on. Among the 503 that

were irradiated 396 were under observation up to Dec. 31, 1926. The rest could not be found. Among the 396 there were 367 cures, or 92.7 per cent; 29, or 7.3 per cent had to be operated on later. Of these 29 seventeen had submucous myomas, 4 myomas and ovarian tumors, 3 myomas that had undergone sarcomatous degeneration, 2 necrotic myomas and one each lymphatic myoma, calcified myoma and an adenomyomatosis of the uterus. There was no mortality from the irradiations and not even any roentgen injury. Of the 529 patients operated on 19 died, or 3.6 per cent. That is not bad, for the mortality of myoma operations is generally between 3 and 5 per cent and these were severe anemic and complicated cases. Five died of pneumonia and the author is not certain that there may not have been embolism in some of them; 4 certainly died of embolism. Patients with myoma occasionally die of embolism even without operation. Two of them died of myoma heart, one of necrotic myoma with a febrile course.

In at least half of all cases of myoma radiotherapy can be used and the patients need not be subjected to operation. Possibly the figure for operations could be still further reduced but some patients demand operation if they have come a long way for that purpose or if for economic or social reasons they feel that they must be freed of the tumor. But there will always be a number of myoma patients who will have to be operated on, for instance complicated myomas, ones with kink of the pedicle, severe disturbances in myoma complicated by pregnancy, incarceration, necrosis (calcification, softening), obscure findings and tumors of the adnexa and malignant degeneration. The two methods of treatment do not enter into competition but each has its indications, between which of course there are transition forms. Radiotherapy is the method of choice in the cases in which it can be used. If it fails or for any reason cannot be used operation must be resorted to.

TESCHENDORF, WERNER. Irradiation of the whole human body in blood diseases. *Strablentherapie*, 1927, xxvi, 720–728.

In order to act on all the places in the body at which leucocytes are formed in leucemias it is necessary to irradiate the whole body. And the distribution of the rays should be as homogeneous as possible. This can be attained by placing the patient on a curved surface and giving half the irradiation from in front and half from the back. With a long focal distance it may be assumed that about 50 per cent of the incident dose is absorbed at half the depth of the body and 25 per cent of it passes out at the lower surface; so 75 per cent of the irradiation is absorbed. The dose of course must be very small. A dose that constitutes weak irradiation when given locally would be dangerous if applied to the whole body. The author used a symmetry apparatus which with 0.5 mm. zinc and 2 mm. aluminum with 190 kv. vertex tension gave an H.E.D. at 30 cm. in 30 minutes. Increasing the distance to 150 cm. the H.E.D. was given in $30 \times 5 \times 5$ or 750 minutes. As only 50 to 75 per cent of the dose is absorbed that increases the time for a full H.E.D. to 1300 minutes, so that in an hour only $\frac{1}{22}$ to $\frac{1}{25}$ H.E.D. was given.

The leucocytes in leucemic patients were greatly decreased by such irradiations in a little while. In one such case the leucocytes fell from 300,000 to 60,000 in a week. Another irradiation was not given until the leucocyte count had remained constant or risen a little on three successive days. In patients with less than 100,000 leucocytes not more than 20–30 minutes of such irradiation was given and in ones with less than 30,000 only 5–10 minutes; this brings the dose down to $\frac{1}{100}$ to $\frac{1}{200}$ H.E.D. The irradiation not only decreased the leucocytes but caused an intense general reaction. There was intense roentgen sickness for three days after doses of 45 minutes, due doubtless to tissue destruction, and from experience in protein therapy the author thinks this not entirely undesirable. The effect seemed to last longest in the cases in which the general reaction was the most intense. Probably this effect can be decreased by giving smaller doses and giving them every day. The spleen was decreased in size by the treatment, though not so much as by direct irradiation of the organ.

The chief advantage of the treatment seems to be that there are no cases that are refractory to it. Cases that no longer reacted to irradiation of the spleen did react to this treatment. Among 7 cases of chronic leucemia irradiated there were remissions of six to eight months in 4. A case of acute myeloblastic leucemia did not respond to the treatment. The effect of the total irradiation was very good in 3 cases of malignant granuloma. It had no effect in pernicious anemia. It is possible that total irradiation may also prove useful in skin diseases and diseases accompanied by vessel spasm.

VOGT, E. The effect of roentgen irradiation on the action of insulin. *Strablentherapie*, 1927, xxvii, 106–120.

These tests were made on normal, nondiabetic pregnant women. They showed that

the action of insulin is increased by irradiation with ultraviolet rays or the roentgen carcinoma dose. It is increased both in intensity and duration. The increased action of insulin under the action of the rays must be due to a change brought about in its chemical composition. The value of the examinations is so far chiefly theoretical. It suggests further investigation of the theory of the action of insulin, the biology of roentgen rays, the theory of internal secretion and the relations between hormones and vitamins. It will require further investigation to show whether it can be utilized in practice.

v. Seuffert, E. R. Radium treatment of benign gynecological diseases. *Strahlentherapie*, 1927, xxvii, 81–105.

If radium is to be used in the treatment of skin affections only dermatological apparatus should be used for if the highly active and highly concentrated preparations are used that are ordinarily used in the treatment of gynecological diseases there is great danger of giving too large a dosage, or if the preparations are placed at a great enough distance to prevent that there is a great loss of radiant energy.

For the internal treatment of strictly gynecological diseases radium can only be applied by placing it in body cavities, such as the uterus or vagina or in openings made for it operatively, such as those of the paravaginal irradiation of Bumm and Warnekros. This means that very small radioactive preparations must be used and that they must therefore be very intense. Therefore the tissues immediately contiguous to the preparation will be affected very intensely and those at a distance very slightly; that is, homegeneity of dosage is impossible. This results in danger of injury to the tissues closest to the preparation. Cases are cited showing that intrauterine application of radium at least is by no means as free of danger as roentgen irradiation so the author concludes that the intrauterine use of radium should not be practiced in cases in which myomas or metropathies can be treated with roentgen rays alone. He thinks the possibility of later conception is also more seriously endangered by radium than by roentgen rays. He cites figures from a number of authors who are advocates of radium treatment, including Schmid and Gauss and Friedrich and from a comparison of their figures with those for roentgen treatment concludes that large tumors are more favorably affected by roentgen rays; there are more serious signs of artificial menopause after radium than after roentgen treatment; radium treatment shows a mortality of 0.1 per cent due to ascending infection while roentgen treatment has no specific mortality. He would use radium even in combination with roentgen rays only intravaginally and not inside the uterus, and chiefly in cases in which there are contraindications to surgery or exclusive roentgen treatment. The technique of the irradiation in such cases is the same as in the use of either method alone, except of course that the intensity of each must be so decreased that overdosage is not given. The two kinds of irradiation should be given as far as possible at the same time. As a rule they can be given at the same time.

Weigand, Hans. The technique of the application of radium in gynecology. *Strahlentherapie*, 1927, xxvii, 54–69.

A number of forms of radium carriers for use in the treatment of tumors of the female genitalia are described and illustrated.

MISCELLANEOUS

Beck, A., and Engel, D. Is the action of rays local or general? *Strahlentherapie*, 1927, xxvi, 729–734.

From their experiments Kok and Vorländer concluded that the action of roentgen rays in the treatment of carcinoma is a general one. But the authors believed that in order to prove this it was necessary to subject the two carcinomas to be compared to the same general conditions and see whether they were influenced by local irradiation. They therefore irradiated an area on one thigh in 12 mice; they were given 140–150 per cent H.E.D., which was borne without any bad effect. This irradiation was given on three successive days and then after two more days a piece of tumor was inoculated into the irradiated thigh and into the normal one. The tumors grew much more rapidly and reached a much larger size on the non-irradiated than on the irradiated sides. This they believe proves that the action of the rays is a local one. But the action is due not only to the injury of the tumor cells themselves but to the effect of the rays on the tumor bed. Clinical experience in human cases too shows how important the reactive capacity of the surrounding tissues is. The rays probably increase the local defensive forces or produce a change in the tumors that is unfavorable to the growth of the cancer.

Burgheim, F. Pathogenesis and treatment of roentgen sickness. *Strahlentherapie*, 1927, xxvii, 297–305.

Determinations of the blood cholesterin content were made in 78 cases of roentgen sickness

and a decreased cholesterin content of the blood found in all of them. In view of the great importance of cholesterin in the cells and in the vegetative nervous system the author believes that this loss of cholesterin is an important factor in the causation of roentgen sickness. This theory is supported by the success he had in treating roentgen sickness with colsil, which is a cholesterin preparation. It is possible that the general disturbances in the condition of roentgenologists and the personnel of roentgen laboratories are also due to decreased cholesterin in the blood.

CHIZZOLA, G. A new instrument for the standardization of roentgen depilation in tinea. *Radiol. med.*, Nov., 1928, xv, 1069–1076.

The author advises following the Kienböck-Adamson technique for the treatment of this disease. He explains the principles and technique of this method, and describes and illustrates an apparatus of his own invention which he has had manufactured in order to make roentgen depilation easier and more exact and overcome all sources of error and all danger. It is composed of a localizing cap for determining the centers of the five fields of irradiation; a tube carrier, an apparatus for centering, a special localizer and a film carrier.

CIGNOLINI, P. Biological action of radium emanation; study of a radioactive spring. *Radiol. med.*, Nov., 1928, xv, 1121–1146.

The biological action of radium emanation is determined by two different factors: the energy of the irradiation and the atomic and molecular systems of the living tissue on which it acts. The author discusses each of these two factors and shows that vital phenomena are based on atomic perturbations due to manifestations of energy similar to or just like those produced by emanations, for radioactivity plays a normal and indispensable part in vital metabolism. He then discusses the present status of treatment by emanation and sketches a plan for utilizing the radioactive springs of Lurisia.

CONTE, ETTORE. Action of secondary radiation on vegetable sprouts. *Radiol. med.*, Nov., 1928, xv, 1077–1086.

The reactions of vegetables to irradiation are very similar to those of animals so that some of the laws of radiobiology have been based on experimentation on plants. Such experiments have shown that the more actively an organism is growing, the more sensitive it is to rays. The author describes a series of experiments on the action of primary and secondary rays on sprouts of *Vicia faba*. The secondary rays were produced by metals with varying atomic weights, such as lead, antimony and zinc. He found that the most intense biological action is produced by the secondary radiation and that the intensity increases in proportion to the increase in the atomic weight of the metal used to produce the secondary radiation. He then discusses the mechanism of action of the different irradiations and the possibility of making practical applications of the different methods of secondary stimulation in irradiated tissues.

FRICKE, HUGO, and MORSE, STERNE. Chemical, colloidal and biological actions of roentgen rays of different wave lengths and their relation to ionization in air. II. Aqueous solution of ferrous sulphate. *Strablentherapie*, 1927, xxvi, 749–756.

This is a continuation of previous work to which reference is made. Mathematical equations are given by which it is possible to determine with sufficient accuracy the relative action of rays of different wave lengths on solutions that do not vary greatly in composition from water. Ferrous sulphate was used in these experiments and curves and tables are given showing the details of the results.

FRICKE, HUGO, and MORSE, STERNE. The use of oxidation of a dilute ferrous sulphate solution as a measure for gauging the roentgen-ray dose. *Strablentherapie*, 1927, xxvi, 757–760.

Little attention has been paid to the use of chemical reactions for standardizing roentgen dosage. The authors think they can be used if certain conditions are fulfilled. The action of the doses to be used for therapeutic purposes must be calculable with sufficient accuracy; the factors on which the reaction rests must be under control and kept constant for a long enough time; any spontaneous change in the irradiated or non-irradiated solution must be negligible, at least for some days; the substance used must not contain any elements whose wave length lies within that of the irradiation in strong enough concentration so that they have any perceptible effect on the absorption of the rays. The solution in suitable cells could be sent by the standardizing laboratory to the different roentgen institutes and after irradiation under the desired conditions sent back to the standardizing laboratory and the analyses made there.

The authors used 1/25,000 ferrous sulphate solution in 0.8 per cent normal sulphuric acid and give a curve and table showing the details

of the results. During the seven days of the experiments there was no systematic change in the effect. A slight spontaneous reduction of the irradiated solution took place. The dose required for complete oxidation of a 1/25,000 molar ferrous sulphate solution was 2.33 kR. For a $\frac{1}{1000}$ molar solution it was 56.7 kR. The proportion of these doses is 24.4, that is, it differs by only 2 per cent from 25, the proportion of the concentrations.

Gassul, R. Action of roentgen rays on living tissue *in vitro*. *Strablentherapie*, 1927, xxvii, 545–560.

Explantation experiments showed that biologically active doses of roentgen rays cause regressive changes in the protoplasm and nuclei. With unfiltered rays there is a phase in which only changes in the protoplasm are seen. The migration of the nuclei in the erythrocytes (frog erythrocytes) indicate osmotic changes in the protoplasm. And the difference in the nature of the carmin storage after filtered and unfiltered irradiation seems to be due to an unequal injury of the cell membrane by soft and hard roentgen rays. De Haan and Höber explain increased storage of vital stains as being due to injury of the membrane which results in greater permeability to certain stains. In this respect young cells were more resistant than older reticuloendothelial cells and began to store the stain more rapidly than normal only after roentgen injury. Lymphocytes and leucocytes were destroyed very quickly after the irradiation, and erythrocyte hemolysis takes place even more quickly. Up to a certain dose roentgen rays of different wave lengths seem to have a different degree of effect on protoplasm and nuclei. There is no doubt that these are phenomena of ionization, and there is no doubt that different kinds of living tissue have specific forms of reaction.

Glasser, Otto. The absolute determination of the unit of dosage "1 Roentgen" at the standardizing station of the Cleveland Clinic. *Strablentherapie*, 1927, xxvii, 160–168.

Behnken in a recent work calls attention to the difference formerly reported of about 50 per cent between the German Roentgen unit and the electrostatic unit used at the Cleveland Clinic, and gives a detailed description of the method he has worked out for determining the German "Roentgen." For purposes of comparison therefore the author gives a detailed description of the instrument and methods in use at the Cleveland Clinic. The theoretical definition of the absolute unit of roentgen dosage, the electrostatic unit, used at Cleveland, is identical with German definition of the R-unit according to Behnken. The air chamber used at Cleveland for standardizing is constructed on the principle of Fricke and has been described in the American Journal of Roentgen and Radium Therapy, 1927, xvii, 611. The possible error in the Cleveland method of measuring the R-unit is less than 3 per cent and the average accuracy of the determination is probably between 1 and 2 per cent. For a mixture of rays produced at 200 kv. and with 0.53 mm. copper filter Portmann, the chief of the roentgen treatment division of the Cleveland Clinic, gave the erythema dose for a field of 20 × 20 cm. and 50 cm. focus distance as 50 minutes. This corresponds to a dose measured in air of 820 R. This dose is considerably higher than the one recently reported by Küstner. With the same conditions but 140 kv. without filter the erythema dose was given as 5 minutes, coresponding to 345 R; this differs in turn from the report recently made by Holthusen and Determann. The author says that every effort is being made to harmonize the Cleveland unit with the German one and they are expecting the arrival of a Wintz-Rump photometer and another Wulf ionometer. But he agrees with Behnken that a comparison of the dosage units at the different laboratories with well-controlled instruments by the same examiner is the best step to be taken in solving this problem.

Grebe, L., and Bickenbach, W. The relation of the R unit to the Sabouraud unit. *Strablentherapie*, 1927, xxvii, 358–363.

The authors give figures and curves showing that the proportion of five generally given in the literature between the Sabouraud unit and the Holzknecht unit does not hold good of the radiometers now being sold. Their measurements show a proportion of the Sabouraud unit to the Holzknecht unit of about 1:8.7. In reading color B of the Sabouraud tablet the use of Meyer's blue lamp is to be preferred to reading in dimmed daylight as the differences in the quality of the daylight may cause considerable differences in the reading. But even with constant reading conditions there are considerable variations in the results which may be as much as 20 per cent for an individual reading. Even with a number of readings the error may be as great as 10 per cent. So the authors believe that measurements with Sabouraud tablets are not sufficiently accurate. But in dermatological practice in which for two decades dosages has been measured almost exclusively with Sabouraud tablets the

method has proved effective and no injuries due to its use have been reported.

After the proportion of the Sabouraud unit to the R unit has been determined the literature in which the Sabouraud unit has been used can be translated into R units. This is important because the Sabouraud measurement has been used most until recently. It is still a disputed question whether the erythema dose for soft rays measured in R units is the same as for hard rays. A translation into R units of the Sabouraud doses reported in the literature seems to show that the value of the erythema dose in R units is lower for soft rays. But the reports in the literature on the biological action in Sabouraud units is not accurate enough to give definite information in regard to the dependence of the biological action on wave length.

HAUSSER, K. W., and SCHLECHTER, E. The skin erythema dose as a biological measure of the action of rays. *Strahlentherapie*, 1927, xxvii, 348–352.

Analogy with long wave ultraviolet rays makes it probable that roentgen erythema rises steeply with an increasing dose after a certain threshold value; this explains the accuracy of the skin erythema dose as a biological measure of the action of roentgen rays. Experiments show that, on the contrary, erythema from the boundary rays rises slowly with an increasing dose. Therefore the adoption of the skin erythema dose as a biological measure for boundary-ray therapy would involve a considerable source of error.

HESS, P. The relation between the hardness of R doses and equivalent erythemas for all the qualities of rays in practical use. *Strahlentherapie*, 1927, xxvii, 146–159.

Equivalent erythema doses were determined for all the qualities of roentgen rays used in superficial and deep therapy by a method independent of the scale of redness produced by the rays. The standard of measurement taken for the equivalent erythema doses was an irradiation of 500 R on a large field with 180 kv. tension and 0.5 zinc and 1.0 mm. aluminum as a filter. The height of the second reaction wave after fifteen to twenty days was chosen as the time for determining the equivalence. On reading in the third reaction wave it was found that the idea of equivalence is not synonymous with biological equality in dosage. Differences in dosage became evident with the method used at 15 per cent. Working out the equivalent doses in R units shows different R doses for different instruments. But the movement of the R values with different qualities of rays is the same and shows a decrease of the R values for the absorbed irradiation in a stretch from 185 to 110 kv. with a filtration of 1.0 mm. copper plus 1 mm. aluminum. But the difference is so slight that on reducing to a fundamental irradiation without any secondary radiation the same erythema doses correspond to the same R values within the limits of biological sensitiveness of ±10 per cent. For irradiations of 60–9 kv. there was at first a considerable fall in the R values which gave place to a rise in the ultrasoft rays. An accurate reproduction of the physical dosage in practice and a determination of the R units in absolute figures is at present impossible on account of lack of agreement in the instruments.

HUMBERT, RENE. Diathermia with interrupted waves and continuous waves. *J. de radiol. et d'électrol.*, Nov., 1928, xii, 546–554.

After having used apparatus which produces interrupted waves for diathermia for years an apparatus has recently been constructed which has a lamp with three electrodes and produces continuous waves. But the author has studied both the physical nature of the oscillations and the physiological results without being able to draw any conclusions in regard to the indications for interrupted or continuous waves in diathermia. It is true that it is too soon to expect a clinical solution of this problem; quite a number of physicians have used the new apparatus but most of them have neglected to report their results. The oral reports the author has been able to obtain indicate that most of the experimenters think the two methods give about the same results. This is not particularly surprising for the heat is after all the chief therapeutic agent and it does not differ greatly with the two methods and the constant wave apparatus has not been used long enough to settle all the details. But certain differences have been reported; for instance d'Arsonval says that apparatus with continuous waves should be used in cases in which heat is particularly indicated while interrupted waves should be used in conditions in which an action on the sympathetic or the glands is desirable. The author believes that the only way to reach reliable conclusions is to take cases as nearly alike clinically as possible and subject them to parallel treatment by the two methods, making the thermic effect as nearly alike as possible, and to repeat with continuous wave apparatus the physiological experiments that have previously been performed with interrupted waves, completing them if possible by new comparative investigations.